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THE WAVE THEORY OF LIGHT.

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[A Lecture delivered at the Academy of Music, Philadelphia, under the auspices of the Franklin Institute, September 29, 1884.]

MR. WILLIAM P. TATHAM, President of the Franklin Institute, introduced the lecturer, who spoke as follows:

SIR WILLIAM THOMSON.—Mr. President, Ladies and Gentlemen: The subject upon which I am to speak to you this evening is happily for me not new in Philadelphia. The beautiful lectures on light which were given several years ago by President Morton, of the Stevens' Institute, and the succession of lectures on the same subject so admirably illustrated by Prof. Tyndall, which many now present have heard, have fully prepared you for anything I can tell you this evening in respect to the wave theory of light.

It is indeed my humble part to bring before you some mathematical and dynamical details of this great theory. I cannot have the pleasure of illustrating them to you by anything comparable with the splendid and instructive experiments which many of you have already seen. It is satisfactory to me to know that so many of you, now present, are so thoroughly prepared to understand anything I can say, that those who have seen the experiments will not feel their absence at this time. At the same time I wish to make them intelligible to those who have not had the advantages to be gained by a systematic course of lectures. I must say in the first place, without further preface, as time

is short and the subject is long, simply that sound and light are both due to vibrations propagated in the manner of waves; and I shall endeavor in the first place to define the manner of propagation and mode of motion that constitute those two subjects of our senses, the sense of sound and the sense of light.

Each is due to vibrations. The vibrations of light differ widely from the vibrations of sound. Something that I can tell you more easily than anything in the way of dynamics or mathematics respecting the two classes of vibrations is, that there is a great difference in the frequency of the vibrations of light when compared with the frequency of the vibrations of sound. The term "frequency" applied to vibrations is a convenient term, applied by Lord Rayleigh in his book on sound to a definite number of full vibrations of a vibrating body per unit of time. Consider, then, in respect to sound, the frequency of the vibrations of notes, which you all know in music represented by letters, and by the syllables for singing, the do, re, mi, etc. The notes of the modern scale correspond to different frequencies of vibrations. A certain note and the octave above it correspond to a certain number of vibrations per second and double that number.

I may explain in the first place conveniently the note called "C"; I mean the middle "C"; I believe it is the C of the tenor voice, that most nearly approaches the tones used in speaking. That note corresponds to two hundred and fifty-six full vibrations per second, two hundred and fifty-six times to and fro per second of time.

Think of one vibration per second of time. The seconds pendulum of the clock performs one vibration in two seconds, or a half vibration in one direction per second. Take a ten-inch pendulum of a drawing-room clock, which vibrates twice as fast as the pendulum of an ordinary eight-day clock, and it gives a vibration of one per second, a full period of one per second to and fro. Now think of three vibrations per second. I can move my hand three times per second easily, and by a violent effort I can move it to and fro five times per second. With four times as great force, if I could apply it, I could move it twice five times per second.

Let us think, then, of an exceedingly muscular arm that would cause it to vibrate ten times per second, that is, ten times to the left and ten times to the right. Think of twice ten times, that is, twenty times per second, which would require four times as much force; three times ten, or thirty times a second, would require nine times as much

force. If a person were nine times as strong as the most muscular arm can be, he could vibrate his hand to and fro thirty times per second, and without any other musical instrument could make a musical note by the movement of his hand which would correspond to one of the pedal notes of an organ.

If you want to know the length of a pedal pipe, you can calculate it in this way. There are some numbers you must remember, and one of them is this. You, in this country, are subjected to the British insularity in weights and measures; you use the foot and inch and yard. I am obliged to use that system, but I apologize to you for doing so, because it is so inconvenient, and I hope all Americans will do everything in their power to introduce the French metrical system. I hope the evil action performed by an English minister whose name I need not mention, because I do not wish to throw obloquy on any one, may be remedied. He abrogated a useful rule, which for a short time was followed and which I hope will soon be again enjoined, that the French metrical system be taught in all our national schools. I do not know how it is in America. The school system seems to be very admirable, and I hope the teaching of the metrical system will not be let slip in the American schools any more than the use of the globes.

I say this seriously. I do not think any one knows how seriously I speak of it. I look upon our English system as a wickedly brain-destroying piece of bondage under which we suffer. The reason why we continue to use it is the imaginary difficulty of making a change and nothing else; but I do not think in America that any such difficulty should stand in the way of adopting so splendidly useful a reform.

I know the velocity of sound in feet per second. If I remember rightly, it is 1,089 feet per second in dry air at the freezing point, and 1,115 feet per second in air of what we call moderate temperature, 59 or 60 degrees—(I do not know whether that temperature is ever attained in Philadelphia or not; I have had no experience of it, but people tell me it is sometimes 59 or 60 degrees in Philadelphia, and I believe them)—in round numbers let us call it 1,000 feet per second. Sometimes we call it a thousand musical feet per second, it saves trouble in calculating the length of organ pipes; the time of vibration in an organ pipe is the time it takes a vibration to run from one end to the other and back. In an organ pipe 500 feet long the period would be

one per second; in an organ pipe ten feet long the period would be 50 per second; in an organ pipe twenty feet long the period would be 25 per second at the same rate. Thus 25 per second, and 50 per second of frequencies correspond to the periods of organ pipes of 20 feet and 10 feet.

The period of vibration of an organ pipe, open at both ends, is approximately the time it takes sound to travel from one end to the other and back. You remember that the velocity in dry air in a pipe 10 feet long is a little more than 50 periods per second; going up to 256 periods per second, the vibrations correspond to those of a pipe two feet long. Let us take 512 periods per second; that corresponds to a pipe about a foot long. In a flute, open at both ends, the holes are so arranged that the length of the sound-wave is about one foot, for one of the chief "open notes." Higher musical notes correspond to greater and greater frequency of vibration, viz., 1,000, 2,000, 4,000 vibrations per second; 4,000 vibrations per second correspond to a piccolo flute of exceedingly small length; it would be but one and a half inches long. Think of a note from a little dog-call, or other whistle, one and a half inches long, open at both ends, or from a little key having a tube three quarters of an inch long, closed at one end; you will then have 4,000 vibrations per second.

A wave length of sound is the distance traversed in the period of vibration. I will illustrate what the vibrations of sound are by this condensation travelling along our picture on the screen. Alternate condensations and rarefactions of the air are made continuously by a sounding body. When I pass my hand vigorously in one direction, the air before it becomes dense, and the air on the other side becomes rarified. When I move it in the other direction these things become reversed; there is a spreading out of condensation from the place where my hand moves in one direction and then in the reverse. Each condensation is succeeded by a rarefaction. Rarefaction succeeds condensation at an interval of one-half what we call "wave lengths." Condensation succeeds condensation at the full interval of what we call wave lengths.

We have here these luminous particles on this scale,* representing portions of the air close together, dense; a little higher up, portions of

* Alluding to a moving diagram of wave motion of sound produced by a working slide for lantern projection.

air less dense. I now slowly turn the handle of the apparatus in the lantern, and you see the luminous sectors showing condensation traveling slowly upwards on the screen; now you have another condensation; making one wave length.

This picture or chart represents a wave length of four feet. It represents a wave of sound four feet long. The fourth part of a thousand is 250. What we see now of the actual scale represents the lower note C of the tenor voice. The air from the mouth of a singer is alternately condensed and rarefied just as you see here.

But that process shoots forward at the rate of one thousand feet per second; the exact period of the motion is 256 vibrations per second for the actual case before you. Follow one particle of the air forming part of a sound wave, as represented by these moving spots of light on the screen; now it goes down, then another portion goes down rapidly; now it stops going down; now it begins to go up; now it goes down and up again.

As the maximum of condensation is approached it is going up with diminishing maximum velocity. The maximum of rarefaction has now reached it, and the particle stops going up and begins to move down. When it is of mean density the particles are moving with maximum velocity, one way or the other. You can easily follow these motions, and you will see that each particle moves to and fro and the thing that we call *condensation* travels along.

I shall show the distinction between these vibrations and the vibrations of light. Here is the fixed appearance of the particles when displaced but not in motion. You can imagine particles of something, the thing whose motion constitutes light. This thing we call the luminiferous ether. That is the only substance we are confident of in dynamics. One thing we are sure of, and that is the reality and substantiality of the luminiferous ether. This instrument is merely a method of giving motion to a diagram designed for the purpose of illustrating wave motion of light. I will show you the same thing in a fixed diagram, but this arrangement shows the mode of motion.

Now follow the motion of each particle. This represents a particle of the luminiferous ether, moving at the greatest speed when it is at the middle position.

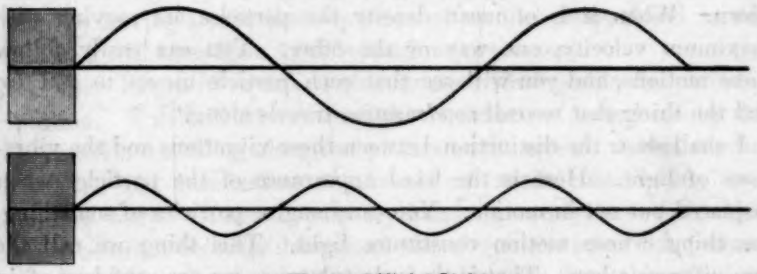
You see the two modes of vibration,* sound and light now moving

* Showing two moving diagrams, simultaneously, on the screen, one depicting a wave motion of light, the other a sound vibration.

together. The travelling of the wave of condensation and rarefaction, and the travelling of the wave of transverse displacement. Note the direction of propagation. Here it is from your left to your right, as you look at it. Look at the motion when made faster. We have now the direction reversed. The propagation of the wave is from right to left, again the propagation of the wave is from left to right; each particle moves perpendicularly to the line of propagation.

I have given you an illustration of the vibration of sound waves, but I must tell you that the movement illustrating the condensation and rarefaction represented in that moving diagram are necessarily very much exaggerated, to let the motion be perceptible, whereas the greatest condensation in actual sound motion is not more than one or two per cent. or a small fraction of a per cent. Except that the amount of condensation was exaggerated in the diagram for sound, you have a correct representation of what actually takes place in the low note C.

On the other hand, in the moving diagram representing light waves what had we? We had a great exaggeration of the inclination of the



line of particles. You must first imagine a line of particles in a straight line, and then you must imagine them disturbed into a wave curve, the shape of the curve corresponding to the disturbance. Having seen what the propagation of the wave is, look at this diagram and then look at that one. This, in light, corresponds to the different sounds I spoke of at first. The wave length of light is the distance from crest to crest of the wave, or from hollow to hollow. I speak of crests and hollows, because we have a diagram of ups and downs as the diagram is placed.

Here, then, you have a wave length.* In this lower diagram you

* Exhibiting a large drawing, or chart, representing a red and a violet wave of light.

have the wave length of violet light. It is but one-half the length of the upper wave of red light; the period of vibration is but half as long. Now, on an enormous scale, exaggerated not only as to slope, but immensely magnified as to wave-length, we have an illustration of the waves of light. The drawing marked "red" corresponds to red light, and this lower diagram corresponds to violet light. The upper curve really corresponds to something a little below the red ray of light in the spectrum, and the lower curve to something beyond the violet light. The variation in length between the most extreme rays is in the proportion of four and a half of red to eight of the violet, instead of four and eight; the red waves are nearly as one to two of the violet.

To make a comparison between the number of vibrations for each wave of sound and the number of vibrations constituting light waves, I may say that 30 vibrations per second is about the smallest number which will produce a musical sound; 50 per second gives one of the grave pedal notes of an organ, 100 or 200 per second give the low notes of the bass voice, higher notes with 250 per second, 300 per second, 1,000, 4,000, up to 8,000 per second give about the shrillest notes audible to the human ear.

Instead of the numbers, which we have, say in the most commonly used part of the musical scale, *i.e.*, from 200 or 300 to 600 or 700 per second, we have millions and millions of vibrations per second in light waves; that is to say, 400 million million per second, instead of 400 per second. That number of vibrations is performed when we have red light produced.

An exhibition of red light travelling through space from the remotest star is due to the propagation by waves or vibrations, in which each individual particle of the transmitting medium vibrates to and fro 400 million million times in a second.

Some people say they cannot understand a million million. Those people cannot understand that twice two makes four. That is the way I put it to people who talk to me about the incomprehensibility of such large numbers. I say *finitude* is incomprehensible, the infinite in the universe *is* comprehensible. Now apply a little logic to this. Is the negation of infinitude incomprehensible? What would you think of a universe in which you could travel one, ten, or a thousand miles, or even to California, and then find it come to an end? Can you suppose an end of matter, or an end of space? The idea is incom-

prehensible. Even if you were to go millions and millions of miles the idea of coming to an end is incomprehensible.

You can understand one thousand per second as easily as you can understand one per second. You can go from one to ten, and ten times ten and then to a thousand without taxing your understanding, and then you can go on to a thousand million and a million million. You can all understand it.

Now 400 million million vibrations per second is the kind of thing that exists as a factor in the illumination by red light. Violet light, after what we have seen and have illustrated by that curve, I need not tell you corresponds to vibrations of 800 million million per second. There are recognizable qualities of light caused by vibrations of much greater frequency and much less frequency than this. You may imagine vibrations having about twice the frequency of violet light and one-fifteenth the frequency of red light and still you do not pass the limit of the range of continuous phenomena only a part of which constitutes *visible* light.

Everybody knows the "photographer's light" and has heard of *invisible* light producing visible effects upon the chemically prepared plate in the camera. Speaking in round numbers, I may say that, in going up to about twice the frequency I have mentioned for violet light you have gone to the extreme end of the range of known light of the highest rates of vibration; I mean to say that you have reached the greatest frequency that has yet been observed.

When you go below visible red light what have you? We have something we do not see with the eye, something that the ordinary photographer does not bring out on his photographically sensitive plates. It is light, but we do not see it. It is something so closely continuous with light visible, that we may define it by the name of invisible light. It is commonly called radiant heat; invisible radiant heat. Perhaps, in this thorny path of logic, with hard words flying in our faces, the least troublesome way of speaking of it is to call it radiant heat. The heat effect you experience when you go near a bright, hot coal fire, or a hot steam boiler; or when you go near, but not over, a set of hot water pipes used for heating a house; the thing we perceive in our face and hands when we go near a boiling pot and hold the hand on a level with it, is radiant heat; the heat of the hands and face caused by a hot fire, or a hot kettle when held under the kettle, is also radiant heat.

You might readily make the experiment with an earthen teapot; it radiates heat better than polished silver. Hold your hands below and you perceive a sense of heat; above the teapot you get more heat; either way you perceive heat. If held over the teapot you readily understand that there is a little current of air rising. If you put your hand under the teapot you get cold air; the upper side of your hand is heated by radiation while the lower side is fanned and is actually cooled by virtue of the heated kettle above it.

That perception by the sense of heat, is the perception of something actually continuous with light. We have knowledge of rays of radiant heat perceptible down to (in round numbers) about four times the wave length, or one-fourth the period of visible, or red light. Let us take red light at 400 million million vibrations per second; then the lowest radiant heat, as yet investigated, is about 100 million million per second in the way of frequency of vibration.

I had hoped to be able to give you a lower figure. Prof. Langley has made splendid experiments on the top of Mount Whitney, at the height of 15,000 feet above the sea level, with his "Bolometer," and has made actual measurements of the wave lengths of radiant heat down to exceedingly low figures. I will read you one of the figures; I have not got it by heart yet, because I am expecting more from him.* I learned a year and a half ago that the lowest radiant heat observed by the diffraction method of Prof. Langley corresponded to 28 one hundred thousandths of a centimetre for wave length, 28 as compared with red light, which is 7·3; or nearly four-fold. Thus wave lengths of four times the amplitude, or one-fourth the frequency per second of red light have been experimented on by Prof. Langley and recognized as radiant heat.

Photographic, or actinic light, as far as our knowledge extends at present, takes us to a little less than one-half the wave length of violet light. You will thus see that while our acquaintance with wave motion below the red extends down to one-quarter of the slowest rate which affects the eye, our knowledge of vibrations at the other

* Since my lecture I have heard from Prof. Langley that he has measured the refrangibility by a rock salt prism, and inferred the wave length of heat rays from a "Leslie cube" (a metal vessel of hot water radiating from a blackened side). The greatest wave length he has thus found is one one-thousandth of a centimetre, which is seventeen times that of sodium light. The corresponding period as about thirty million million to the second.

W. T.

end of the scale only comprehends those having twice the frequency of violet light. In round numbers we have 4 octaves of light, corresponding to 4 octaves of sound in music. In music the octave has a range to a note of double frequency. In light we have one octave of visible light, one octave above the visible range and two octaves below the visible range. We have 100 per second, 200 per second, 400 per second (million million understood) for invisible radiant heat, 800 per second for visible light, and 1,600 per second for invisible light.

One thing in common to the whole is the heat effect. It is extremely small in moonlight, so small that nobody until recently knew there was any heat in the moon's rays. Herschel thought it was perceptible in our atmosphere by noticing that it dissolved away very light clouds, an effect which seemed to show in full moonlight more than when we have less than full moon. Herschel, however, pointed this out as doubtful, but now, instead of its being a doubtful question, we have Prof. Langley giving as a fact that the light from the moon drives the indicator of his sensitive instrument clear across the scale and with a comparatively prodigious heating effect!

I must tell you that if any of you want to experiment with the heat of moonlight you must compare the heat with whatever comes within the influence of the moon's rays only. This is a very necessary precaution; if, for instance, you should take your Bolometer or other heat detector from a comparatively warm room into the night air, you would obtain an indication of a fall in temperature owing to this change. You must be sure that your apparatus is in thermal equilibrium with the surrounding air, then take your burning-glass, and first point it to the moon and then to space in the sky beside the moon; you thus get a differential measurement in which you compare the radiation of the moon with the radiation of the sky. You will then see that the moon has a distinctly heating effect.

To continue our study of visible light, that is, undulations extending

The Solar Spectrum.

from red to violet in the spectrum (which I am going to show you presently), I would first point out on this chart that in the section from letter "*A*" to letter "*D*" we have visual effect and heating effect only;

but no ordinary chemical or photographic effect. Photographers can leave their usual sensitive, chemically prepared plates exposed to yellow light and red light without experiencing any sensible effect; but when you get toward the blue end of the spectrum the photographic effect begins to tell, more and more as you get toward the violet end. When you get beyond the violet there is the invisible light known chiefly by its chemical action. From yellow to violet we have visual effect, heating effect and chemical effect, all three; above the violet only chemical and heating effects and so little of the heating effect that it is scarcely perceptible.

The prismatic spectrum is Newton's discovery of the composition of white light. White light consists of every variety of color from red to violet. Here, now, we have Newton's prismatic spectrum produced by a prism. I will illustrate a little in regard to the nature of color by putting something before the light which is like colored glass; it is colored gelatin. I will put in a plate of red gelatin which is carefully prepared of chemical materials and see what that will do. Of all the light passing to it from violet to red it only lets through the red and orange, giving a mixed reddish color.

Here is another plate of green gelatin. The green absorbs all the red, giving only green. Here is another plate absorbing something from each portion of the spectrum, taking away a great deal of the violet and giving a yellow or orange appearance to the light. Here is another absorbing out the green, leaving red, orange, and a very little faint green, and absorbing out all the violet.

When the spectrum is very carefully produced, far more perfectly than Newton knew how to show it, we have a homogeneous spectrum. It must be noticed that Newton did not understand what we call a homogeneous spectrum; he did not produce it, and does not point out in his writings the conditions for producing it. With an exceedingly fine line of light we can bring it out as in sunlight, like this upper picture, red, orange, yellow, green, blue, indigo and violet according to Newton's nomenclature. Newton never used a narrow beam of light, and so could not have had a homogeneous spectrum.

This is a diagram painted on glass and showing the colors as we know them. It would take two or three hours if I were to explain the subject of spectrum analysis to-night. We must tear ourselves away from it. I will just read out to you the wave lengths corresponding to the different positions in the sun's spectrum of certain dark

lines commonly called "Fraunhofer's lines." I will take as a unit the one-hundredth thousandth of a centimetre. A centimetre is ·4 of an inch; it is a rather small half an inch. I take the thousandth of a centimetre and the hundredth of that as a unit. At the red end of the spectrum the light in the neighborhood of that black line "*A*" has for its wave length 7·6; "*B*" has 6·87; "*D*" has 5·89; the "frequency" for "*A*" is 3·9 times 100 million million; the frequency of "*D*" light is 5·1 times 100 million million per second.

Now what force is concerned in those vibrations as compared with sound at the rate of 400 vibrations per second; suppose for a moment the same matter was to move to and fro through the same range but 400 million million times per second. The force required is as the square of the number expressing the frequency. Double frequency would require quadruple force for the vibration of the same body. Suppose I vibrate my hand again, as I did before. If I move it once per second a moderate force is required; for it to vibrate ten times per second 100 times as much force is required; for 400 vibrations per second 160,000 times as much force.

If I move my hand once per second through a space of quarter of an inch a very small force is required; it would require very considerable force to move it ten times a second, even through so small a range; but think of the force required to move a tuning fork 400 times a second; compare that with the force required for a motion of 400 million million times a second. If the mass moved is the same, and the range of motion is the same, then the force would be one million million million million times as great as the force required to move the prongs of the tuning fork. It is as easy to understand that number as any number like 2, 3, or 4.

Consider gravely what that number means and what we are to infer from it. What force is there in space between my eye and that light? What forces are there in space between our eyes and the sun and our eyes and the remotest visible star? There is matter and there is motion, but what magnitude of force may there be?

I move through this "luminiferous ether" as if it were nothing. But were there vibrations with such frequency in a medium of steel or brass, they would be measured by millions and millions and millions of tons action on a square inch of matter. There are no such forces in our air. Comets make a disturbance in the air and perhaps the luminiferous ether is split up by the motion of a comet through it. So

when we explain the nature of electricity, we explain it by a motion of the luminiferous ether. We cannot say that it is electricity. What can this luminiferous ether be? It is something that the planets move through with the greatest ease. It permeates our air; it is nearly in the same condition, so far as our means of judging are concerned, in our air and in the inter-planetary space. The air disturbs it but little; you may reduce air by air pumps to the hundredth thousandth of its density, and you make little effect in the transmission of light through it. The luminiferous ether is an elastic solid. The nearest analogy I can give you is this jelly which you see.* The nearest analogy to the waves of light is the motion, which you can imagine, of this elastic jelly, with a ball of wood floating in the middle of it. Look there, when with my hand I vibrate the little red ball up and down, or when I turn it quickly round the vertical diameter, alternately in opposite directions;—that is the nearest representation I can give you of the vibrations of luminiferous ether.

Another illustration is Scottish shoemaker's wax or Burgundy pitch, but I know Scottish shoemaker's wax better. It is heavier than water and absolutely answers my purpose. I take a large slab of the wax, place it in a glass jar filled with water, place a number of corks on the lower side and bullets on the upper side. It is brittle like the Trinidad pitch or Burgundy pitch which I have in my hand. You can see how hard it is, but if left to itself it flows like a fluid. The shoemaker's wax breaks with a brittle fracture, but it is viscous and gradually yields.

What we know of the luminiferous ether is that it has the rigidity of a solid and gradually yields. Whether or not it is brittle and cracks we cannot yet tell, but I believe the discoveries in electricity and the motions of comets and the marvelous spurts of light from them, tend to show cracks in the luminiferous ether—show a correspondence between the electric flash and the aurora borealis and cracks in the luminiferous ether. Do not take this as an assertion, it is hardly more than a vague scientific dream: but you may regard the existence of the luminiferous ether as a reality of science, that is, we have an all-pervading medium, an elastic solid, with a great degree of rigidity; its rigidity is so prodigious in proportion to its density that the vibra-

* Exhibiting a large bowl of clear jelly with a small red wooden ball imbedded in the surface near the centre.

tions of light in it have the frequencies I have mentioned, with the wave lengths I have mentioned.

The fundamental question as to whether or not luminiferous ether has gravity has not been answered. We have no knowledge that the luminiferous ether is attracted by gravity; it is sometimes called imponderable because some people vainly imagine that it has no weight. I call it matter with the same kind of rigidity that this elastic jelly has.

Here are two tourmalines; if you look through them toward the light you see the white light all round, *i. e.* they are transparent. If I turn round one of these tourmalines the light is extinguished, it is absolutely black, as though the tourmalines were opaque. This is an illustration of what is called polarization of light. I cannot speak to you about qualities of light without speaking of the polarization of light. I want to show you a most beautiful effect of polarizing light, before illustrating a little further by means of this large mechanical illustration which you have in the bowl of jelly. Now I put in the lantern another instrument called a "Nicol prism." What you saw first were two plates of the crystal tourmaline which came from Brazil, I believe, having the property of letting light pass when both plates are placed in one particular direction as regards their axes of crystallization, and extinguishing it when it passes through the first plate held in another direction. We have now an instrument which also gives rays of polarized light. A Nicol prism is a piece of Iceland spar, cut in two and turned, one part relatively to the other in a very ingenious way, and put together again and cemented into one by Canada balsam. The Nicol prism takes advantage of the property which the spar has of double refraction, and produces the phenomenon which I now show you.

I turn one prism round in a certain direction and you get light, a maximum of light. I turn it through a right angle and you get blackness. I turn it one quarter round again and get maximum light; one quarter more, maximum blackness; one quarter more and bright light. We rarely have such a grand specimen of a Nicol prism as this.

There is another way of producing polarized light. I stand before that light and look at its reflection in a plate of glass on the table through one of the Nicol prisms, which I turn round, so. Now I must incline that piece of glass at a particular angle, rather more than forty-five degrees; I find a particular angle in which, if I look at it

and then turn the prism round in the hand, the effect is absolutely to extinguish the light in one position and to give it maximum brightness in another position. I use the term "absolute" somewhat rashly. It is only a reduction to a very small quantity of light, not an absolute annulment as we have in the case of the two Nicol prisms used conjointly. Those of you who have never heard of this before would not know what I am talking about. As to the mechanics of the thing it could only be explained to you by a course of lectures in physical optics. The thing is this, vibrations of light must be in a definite direction relatively to the line in which the light travels.

Look at this diagram, the light goes from left to right; we have vibrations perpendicular to the line of transmission. There is a line up and down which is the line of vibration. Imagine here a source of light, violet light, and here in front of it is the line of propagation. Sound vibrations are to and fro; this is transverse to the line of propagation. Here is another, perpendicular to the diagram, still following the law of transverse vibration; here is another circular vibration. Imagine a long rope, you whirl one end of it and you send a screw like motion running along; you can get the circular motion in one direction or in the opposite.

Plane polarized light is light with the vibrations all in a single plane, perpendicular to the plane through the ray which is technically called the "plane of polarization." Circular polarized light consists of undulations of luminiferous ether having a circular motion. Elliptically polarized light is something between the two, not in a straight line, and not in a circular line; the course of vibration is an ellipse. Polarized light is light that performs its motions continually in one mode or direction. If in a straight line it is plane polarized; if in a circular direction it is circularly polarized light; when elliptical it is elliptically polarized light.

With Iceland spar, one unpolarized ray of light divides on entering it into two rays of polarized light, by reason of its power of double refraction, and the vibrations are perpendicular to one another in the two emerging rays. Light is always polarized when it is reflected from a plate of unsilvered glass, or water, at a certain definite angle of fifty-six degrees for glass, fifty-two degrees for water, the angle being reckoned in each case from a perpendicular to the surface. The angle for water is the angle whose tangent is 1·4. I wish you to look at the polarization with your own eyes. Light from glass at fifty-six

degrees and from water at fifty-two degrees goes away vibrating perpendicularly to the plane of incidence and plane of reflection.

We can distinguish it without the aid of an instrument. There is a phenomenon well known in physical optics as "Haidinger's Brushes." The discoverer is well known in Philadelphia as a mineralogist, and the phenomenon I speak of goes by his name. Look at the sky in a direction of ninety degrees from the sun, and you will see a yellow and blue cross, with the yellow toward the sun, and from the sun, spreading out like two foxes tails with blue between, and then two red brushes in the space at right angles to the blue. If you do not see it, it is because your eyes are not sensitive enough, but a little training will give them the needed sensitiveness.

If you cannot see it in this way try another method. Look into a pail of water with a black bottom; or take a clear glass dish of water, rest it on a black cloth and look down at the surface of the water on a day with a white cloudy sky (if there is such a thing ever to be seen in Philadelphia). You will see the white sky reflected in the basin of water at an angle of about fifty degrees. Look at it with the head tipped to one side and then again with the head tipped to the other side, keeping your eyes on the water, and you will see Haidinger's brushes. Do not do it fast or you will make yourself giddy. The explanation of this is the refreshing of the sensibility of the retina. The Haidinger's brush is always there, but you do not see it because your eye is not sensitive enough. After once seeing it you always see it; it does not thrust itself inconveniently before you when you do not want to see it. You can readily see it in a piece of glass with dark cloth below it, or, in a basin of water.

I am going to conclude by telling you how we know the wave lengths of light and how we know the frequency of the vibrations. We shall actually make a measurement of the wave length of the yellow light. I am going to show you the diffraction spectrum.

You see on the screen,* on each side of a central white bar of light, a set of bars of light variegated colors, the first one, on each side, showing blue or indigo color, about four inches from the central white bar and red about four inches farther, with vivid green between the blue and the red. That effect is produced by a grating with 400 lines

* Showing the chromatic bands thrown upon the screen from a diffraction grating.

to the centimetre, engraved on glass, which I now hold in my hand. The next grating has 3,000 lines on a Paris inch. You see the central space and on each side a large number of spectrums, blue at one end and red at the other. The fact that, in the first spectrum, red is about twice as far from the centre as the blue, proves that a wave length of red light is double that of blue light.

I will now show you the operation of measuring the length of a wave of sodium light, that is a light like that marked "*D*" on the spectrum, a light produced by a spirit lamp with salt in it. The sodium vapor is heated up to several thousand degrees, when it becomes self luminous and gives such a light as we get by throwing salt upon a spirit lamp in the game of snap dragon.

I hold in my hand a beautiful grating of glass silvered by Liebig's process with metallic silver, a grating with 6,480 lines to the inch, belonging to my friend Prof. Barker, which he has kindly brought here for us this evening. You will see the brilliancy of color as I turn the light reflected from the grating toward you and pass the beam round the room. You have now seen directly with your own eyes these brilliant colors reflected from the grating, and you have also seen them thrown upon the screen from a grating placed in the lantern. With a grating of 17,000 lines—a much greater number of lines per inch than the other—you will see how much further from the central bright space the first spectrum is; how much more this grating changes the direction or diffraction of the beam of light. Here is the centre of the grating, and there is the first spectrum. You will note that the violet light is least diffracted and the red light is most diffracted. This diffraction of light first proved to us definitely the reality of the undulatory theory of light.

You ask why does not light go round a corner as sound does. Light does go round a corner in these diffraction spectrums; it is shown going round a corner, it passes through these bars and is turned round an angle of thirty degrees. Light going round a corner by instruments adapted to show the result, and to measure the angles at which it is turned, is called the diffraction of light.

I can show you an instrument which will measure the wave lengths of light. Without proving the formula, let me tell it to you. A spirit lamp with salt sprinkled on the wick gives very nearly homogeneous light, that is to say, light all of one wave length, or all of the same period. I have a little grating which I take in my hand. I look

through this grating and see that candle before me. Close behind it you see a blackened slip of wood with two white marks on it ten inches asunder. The line on which they are marked is placed perpendicular to the line at which I shall go from it. When I look at this salted spirit lamp I see a series of spectrums of yellow light. As I am somewhat short-sighted I am making my eye see with this eyeglass and the natural lenses of the eye what a long-sighted person would make out without an eyeglass. On that screen you saw a succession of spectrums. I now look direct at the candle and what do I see? I see a succession of five or six brilliantly colored spectrums on each side of the candle. But when I look at the salted spirit lamp, now I see ten spectrums on one side and ten on the other, each of which is a monochromatic band of light.

I will measure the wave lengths of light thus. I walk away to a considerable distance and look at the candle and marks. I see a set of spectrums. The first white line is exactly behind the candle. I want the first spectrum to the right of that white line to fall exactly on the other white line, which is ten inches from the first. As I walk away from it I see it is now very near it; it is now on it. Now the distance from my eye is to be measured and the problem is again to reduce feet to inches. The distance from the spectrum of the flame to my eye is thirty-four feet nine inches. Mr. President, how many inches is that? 417 inches, in round numbers 420 inches. Then we have the proportion, as 420 is to 10 so is the length from bar to bar of the grating to the wave length of sodium light. That is to say as forty-two is to one. The distance from bar to bar is the four hundredth of a centimetre: therefore the 42d part of the four hundredth of a centimetre is the required wave length, or the 16,800th of a centimetre is the wave length according to our simple, and easy and hasty experiment. The true wave length of sodium light, according to the most accurate measurement, is about a 17,000th of a centimetre, which differs by scarcely more than one per cent. from our result!

The only apparatus you see is this little grating; it is a piece of glass with four-tenths of an inch ruled with 400 fine lines. Any of you who will take the trouble to buy one may measure the wave lengths of a candle flame himself. I hope some of you will be induced to make the experiment for yourselves.

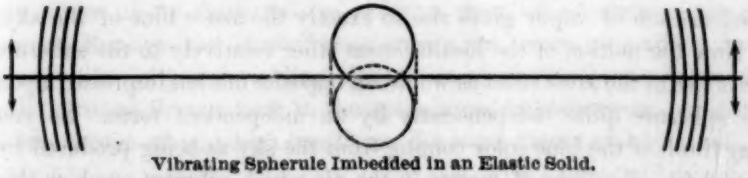
If I put salt on the flame of a spirit lamp, what do I see through this grating? I see merely a sharply defined yellow light, constitut-

ing the spectrum of vaporized sodium, while from the candle flame I see an exquisitely colored spectrum, far more beautiful than I showed you on the screen. I see in fact a series of spectrums on the two sides with the blue toward the candle flame and the red further out. I cannot get one definite thing to measure from in the spectrum from the candle flame as I can with the flame of a spirit lamp with the salt thrown on it, which gives as I have said a simple yellow light. The highest blue light I see in the candle flame is now exactly on the line. Now measure to my eye, it is forty-four feet four inches, or 532 inches. The length of this wave then is the 532d part of the four hundredth of a centimetre which would be the 21,280th of a centimetre, say the 21,000th of a centimetre. Then measure for the red and you would find something like the 11,000th for the lowest of the red light.

Lastly, how do we know the frequency of vibration?

Why, by the velocity of light. How do we know that? We know it in a number of different ways, which I cannot explain now because time forbids. Take the velocity of light. It is 187,000 British statute miles per second. But it is much better to take a kilometre for the unit. That is about six-tenths of a mile. The velocity is very accurately 300,000 kilometers per second; that is 30,000,000,000 centimetres per second. Take the wave length as the 17,000th of a centimetre and you find the frequency of the sodium light to be 510 million million per second. There, then, you find a calculation of the frequency from a simple observation which you can all make for yourselves.

Lastly, I must tell you about the color of the blue sky which was illustrated by the spherule imbedded in an elastic solid. I want to



Vibrating Spherule Imbedded in an Elastic Solid.

explain to you in two minutes the mode of vibrations. Take the simplest plane-polarized light. Here is a spherule which is producing it in an elastic solid. Imagine the solid to extend miles horizontally and miles down, and imagine this spherule to vibrate up and down. It is quite clear that it will make transverse vibrations similarly in

all horizontal directions. The plane of polarization is defined as a plane perpendicular to the line of vibration. Thus, light produced by a molecule vibrating up and down, as this red globe in the jelly before you, is polarized in a horizontal plane because the vibrations are vertical.

Here is another mode of vibrations. Let me twist this spherule in the jelly as I am doing it, and that will produce vibrations, also spreading out equally in all horizontal directions. When I twist this globe round it draws the jelly round with it; twist it rapidly back and the jelly flies back. By the inertia of the jelly the vibrations spread in all directions and the lines of vibration are horizontal all through the jelly. Everywhere, miles away that solid is placed in vibration. You do not see it, but you must understand that they are there. If it flies back it makes vibration, and we have waves of horizontal vibrations traveling out in all directions from the exciting molecule.

I am now causing the red globe to vibrate to and fro horizontally. That will cause vibrations to be produced which will be parallel to the line of motion at all places of the plane perpendicular to the range of the exciting molecule. What makes the blue sky? These are exactly the motions that make the blue light of the sky which is due to spherules in the luminiferous ether, but little modified by the air. Think of the sun near the horizon, think of the light of the sun streaming through and giving you the azure blue and violet overhead. Think first of any one particle of the sun and think of it moving in such a way as to give horizontal and vertical vibrations and what not of circular and elliptic vibrations.

You see the blue sky in high pressure steam blown into the air; you see it in the experiment of Tyndall's blue sky in which a delicate condensation of vapor gives rise to exactly the azure blue of the sky.

Now the motion of the luminiferous ether relatively to the spherule gives rise to the same effect as would an opposite motion impressed upon the spherule quite independently by an independent force. So you may think of the blue color coming from the sky as being produced by to and fro vibrations of matter in the air which vibrates much as this little globe vibrates imbedded in the jelly.

The result in a general way is this: The light coming from the blue sky is polarized in a plane through the sun, but the blue light of the sky is complicated by a great number of circumstances and one of them is this, that the air is illuminated not only by the sun but by the

earth. If we could get the earth covered by a black cloth then we could study the polarized light of the sky with simplicity, which we cannot do now. There are, in nature, reflections from seas and rocks and hills and waters in a indefinitely complicated manner.

Let observers observe the blue sky not only in winter when the earth is covered with snow, but in summer when it is covered with dark green foliage. This will help to unravel the complicated phenomena in question. But the azure blue of the sky is light produced by the reaction on the vibrating ether of little spherules of water, of perhaps a fifty thousandth or a hundred thousandth of a centimetre diameter, or perhaps little motes, or lumps, or crystals of common salt, or particles of dust, or germs of vegetable or animal species wafted about in the air. Now what is the luminiferous ether? It is matter prodigiously less dense than air—millions and millions and millions of times less dense than air. We can form some sort of idea of its limitations. We believe it is a real thing, with great rigidity in comparison with its density, and it may be made to vibrate 400 million million times per second, and yet with such rigidity as not to produce the slightest resistance to any body going through it.

Going back to the illustration of the shoemaker's wax; if a cork will in the course of a year push its way up through a plate of that wax when placed under water, and if a lead bullet will penetrate downwards to the bottom, what is the law of the resistence? It clearly depends on time. The cork slowly in the course of a year works its way up through two inches of that substance; give it one or two thousand years to do it and the resistance will be enormously less; thus the motion of a cork or bullet, at the rate of one inch in 2,000 years, may be compared with that of the earth, moving at the rate of six times ninety-three million miles a year, or nineteen miles per second, through the luminiferous ether; but when we have a thing elastic like jelly and yielding like pitch, surely we have a large and solid ground for our faith in the speculative hypothesis of an elastic luminiferous ether, which constitute, the wave theory of light.

Mr. Tatham—On behalf of the members of the Franklin Institute I desire publicly to return thanks to Professor Sir William Thomson for his instructive lecture.

HARMONIC MOTION IN STELLAR SYSTEMS.

By Pliny Earle Chase, LL.D.

[Read at the Philadelphia Meeting of the American Association for the Advancement of Science.]

The principle of harmonic motion is of "immense use, not only in ordinary kinetics, but in the theories of sound, light, heat, etc." (Thomson and Tait, *Nat. Phil.*, i, sec. 52).

In applying the doctrine of conservation of energy to the nebular hypothesis, the principles of universal gravitation and of æthereal oscillation are simultaneously and mutually operative, in ways which are indicated, as I think, by observable relations among cosmical masses, distances, velocities and orbital periods. Among the evidences of far-reaching kinetic correlation the following seem to be worthy of special consideration:

1. Cosmical masses and æthereal waves are in contact and in relative motion. If the luminiferous æther is subject to gravitation, the waves are under conditions of impact, in which gravity acts constantly towards the cosmical centres. The oscillating time-integral, gt, should therefore have an important kinetic significance. If g represents the greatest gravitating acceleration in our stellar system (g at Sun's surface), and t represents the time required to convert centripetal acceleration into circular-orbital revolution which is synchronous with solar rotation, the time-integral is *the velocity of light* (v_λ).

2. Centrifugal radiation may be considered as opposed by centripetal gravitation. The total cyclical resistance is measured by the same time-integral, $gt = v_\lambda$.

3. According to the electro-magnetic theory of light, the ratio of the electric units may be represented by the same time-integral, $v_e = gt = v_\lambda$.

4. In the plane of luminous undulation, the electrical disturbance parallel to the equatorial tangent and the magnetic disturbance parallel to the axis suggest the application of Coulomb's formula of torsional elasticity:

$$f = \frac{m}{2} = \frac{W}{2} \cdot \frac{\pi^2 a^2 r_e}{gt^2}; \quad \therefore \pi^2 a^2 r_e = gt^2 = \pi^2 l.$$

In this formula, if r_e = Sun's semidiameter, we have the same time-integral, $gt = v_\lambda$.

5. Harmonic motions, both simple and cumulative, are indicated by the following equations: $gt_\alpha = \frac{2}{\pi} v_\varepsilon$; $gt_\beta = v_p$; $gt_\gamma = v_\lambda$. In these equations, t_α = time in which a luminous undulation would traverse Sun's diameter; v_ε = equatorial velocity of solar rotation; t_β = time in which solar superficial gravitation would communicate parabolic velocity, or velocity of infinite fall; t_γ = solar cyclical period of half rotation, giving the same time-integral, $gt = v_\lambda$.

6. Various forms of cyclical oscillation, representing the immediate combined control of inertia, attraction and repulsion, may be denoted and co-ordinated by the formula

$$gt^2 = \pi^2 l = \pi^2 L^2 l_0 = M = 2h.$$

In this formula g represents gravitating acceleration; t = cyclical time of a single oscillation (or half time of rotation or of revolution); l = length of linear pendulum, or radius of circular-orbital revolution; L = quotient of minimum radius of free revolution by radius of synchronous constrained nucleal rotation, as explained in a following paragraph; $l_0 = \rho_0$ = radius of solar or stellar nucleus; M = modulus, or height of homogeneous elastic atmosphere which would propagate waves with velocity gt; h = height of fall in time t, or of projection against constant g by projectile velocity gt, or of alternate fall and rise in perpetual elastic rebound with maximum velocity gt.

At Sun's surface, where the collisions of subsiding particles have changed free revolution into constrained rotation, the time-integral gt, as we have seen, $= v_\lambda$.

In free circular orbital revolution, $t \propto r^{\frac{1}{2}}$; but in the spiral paths of particles in an expanding or contracting rotating nucleus, t varies, either exactly or very nearly, as r^2, while $g \propto \frac{1}{r^2}$. Therefore, gt is nearly or quite* constant, and we have reason to believe that the modulus velocity of æthereal oscillation, of nucleal rotation, of electric

* The most recent investigations of Earth's ellipticity, by Fischer, Listing, Jordan and Clarke, seem, by analogy, to increase the probability that the mean constancy is complete, the æthereal rigidity and strain producing such "flow of solids" and oblateness of interior strata (Thomson and Tait, *op. cit.*, sec. 821) as are required for stability of figure. If there has been the same extent of constancy in the Sun as there appears to have been in the Earth, the solar oblateness has not yet reached $\frac{1}{300}$.

ratio, of solar torsion and of limiting gravitating acceleration, has been, is and will continue to be, v_λ. This gives the universal equation

$$g = \frac{v_\lambda}{t} \cdot \frac{m}{r^2}$$

for all masses and distances, provided m and r are expressed in terms of Sun's mass and semidiameter.

Laplace (Bowditch's translation, III, vii, §47 [2128²]) shows that the solar "atmosphere can extend no farther than to the orbit of a planet whose periodical revolution is performed in the same time as the sun's rotatory motion about its axis." Faye (*Comptes Rendus*, April 21, 1884, p. 949) traces the indication of this limit to Kant. I designate it, therefore, by ρ_k, Sun's semidiameter being $\rho_\circ$, and $L = \rho_k \div \rho_\circ$. It may be deduced as follows:

Let l = length of a pendulum, measured from the point of suspension to the centre of oscillation; $\frac{3}{2} l$ = total length of a synchronous linear pendulum; $\frac{3}{2} \pi^2 l$ = corresponding radius of constrained rotation $= \rho_\circ$; $(\frac{3}{2} \pi^2)^{\frac{1}{3}} \rho_\circ = \rho_k = 36{\cdot}35\rho_\circ$.* Combining this result with the British Nautical Almanac estimate of Sun's apparent semidiameter, 961·82″, we find the following values:

$$n = \rho_s \div \rho_\circ = 206264{\cdot}806'' \div 961{\cdot}82'' = 214{\cdot}45 \quad 7$$

$$v_\circ = \sqrt{g_\circ \rho_\circ} = 2\pi\rho_\circ \times n^{\frac{1}{2}} \div 31558149 = {\cdot}0006252554\rho_\circ \quad 8$$

$$v_\lambda \div v_\circ = \pi L^{\frac{3}{2}} = 688{\cdot}544 \quad 9$$

$$v_r = v_\circ \div L^{\frac{1}{2}} = {\cdot}0000028528\rho_\circ \quad 10$$

$$M = \pi^2 L^3 \rho_\circ = 474093\rho_\circ \quad 11$$

$$v_\lambda = {\cdot}43056\rho_\circ = g_\circ t \quad 12$$

$$t = M \div v_\lambda = 1101221 \text{ s.} = 12{\cdot}746 \text{ dys.} \quad 13$$

$$g_\circ = v_\lambda \div t = {\cdot}000000390944\rho_\circ = v_\circ^2 \div \rho_\circ \quad 14$$

$$t_\lambda = 214{\cdot}45\rho_\circ \div v_\lambda = 498{\cdot}123^s \quad 15$$

$$C_a = 1296000'' \times t_\lambda \div 31558149^s = 20{\cdot}456'' \quad 16$$

Nyrén's estimate of the constant of aberration (C_a; see *The Observatory*, vi, 365) is 20·492."

Equations 8, 10, 11, 12, 14 contain the factor $\rho_\circ$, which could be

* The nucleal radius $\propto t^{\frac{1}{2}}$, while the atmospheric radius $\propto t^{\frac{3}{2}}$; $\therefore \rho_k \propto \rho_\circ^{\frac{1}{3}}$.

readily found if we knew the quotient of Sun's mass by Earth's mass, $m_0 \div m_3$. The great ratio of æthereal elasticity to density may be expected to introduce various harmonic relations of mass. For a clue to some of those relations we may reasonably look to gravitating potential and æthereal oscillation. The ordinary expression for gravitating potential represents a *vis viva* in the plane of luminous oscillation, but for thermodynamic reasons we may also look for a radial *vis viva*, dependent upon the central mass and the sum of the squares of gravitating acceleration on all æthereal particles during the mean interval of a luminous wave.

A *vis viva* of this kind would be proportional to the cube of the mass. In the resultant cyclic harmonies which have given stability to our stellar system, there are evidences of direct and reciprocal, æthereal and cosmical, *vis viva* and momentum, as is shown by the following proportions:

$$m_3^3 : m_0 m_3 m_5 :: \mu v_3^2 : \mu v_\lambda^2 \qquad 17$$

$$m_5^3 : m_0 m_3 m_6 :: \mu v_\beta : \mu v_0 \qquad 18$$

$$m_5^3 : m_6^3 :: \mu v_0^2 :: \mu v_k^2 :: \rho_k : \rho_0 \qquad 19$$

$$(m_1 + m_4)^3 : (m_2 + m_3)^3 :: (m_7 + m_8)^3 : m_5^3 :: V_l : V_\mu :: 1 : \pi^6 \qquad 20$$

$$m_2^3 : m_3^3 :: m_2 v_3^2 : m_3 v_2^2 :: t_2 : t_3 \qquad 21$$

$$m_1^3 : m_4^3 :: \mu v_4^2 : \mu v_1^2 :: \rho_1 : \rho_4 \qquad 22$$

$$m_7^3 : m_8^3 :: \mu v_8^2 : \mu v_7^2 :: \rho_7 : \rho_8 \qquad 23$$

These proportions furnish the following indications respecting the order and rationale of cosmic development.

17_1. Earth, m_3, has a subsidence *vis viva*, which bears the same ratio to the mean subsidence *vis viva* of Sun (m_0), Earth and Jupiter (m_5), as æthereal *vis viva* in Earth's orbit (μv_3^2) bears to *vis viva* of luminous radiation (μv_λ^2). The early establishment and segregation of the terrestrial nucleus are also indicated by the position of the orbit in the centre of the belt of greatest condensation (secular perihelion of $m_1 = \cdot 2974\rho_3$; secular aphelion of $m_4 = 1\cdot 7365\rho_3$), and by the equivalence between the radial momentum which luminous undulation tends to give the Earth (mv_λ) and the mean momentum which Earth's orbital velocity tends to give to Sun and Jupiter ($v_3 \sqrt{m_0 m_5}$). I called attention to the first of these facts, and to its importance, in 1877, (Proc. Amer. Phil. Soc., xvi, 501). Faye has introduced it into his late modifications of the hypotheses of Kant and Laplace (*Comptes Rendus*,

April 21, 1884). The additional confirmation which it lends to the Mosaic cosmogony is noteworthy. It may also be well to remark that the mean value of Sun, Earth and Jupiter, $(m_0 m_3 m_5)^{\frac{1}{3}}$, is about $\frac{1}{0\,0}\,m_0$, thus including the whole planetary mass, together with about $_1\frac{1}{0}$ of Sun's mass.

18_1. The subsidence *vis viva* of Jupiter (m_5) is to the mean subsidence *vis viva* of Sun, Earth and Saturn (m_6), as æthereal momentum with orbital velocity at mean centre of gravity of Sun and Jupiter ($\mu v_{\bar{5}}$), is to æthereal momentum with limiting orbital velocity at Sun's surface (μv_0). The significance of this fact is increased by Jupiter's central position in the primitive nebula, between Neptune in conjunction and Uranus in opposition.

19_1. Saturn's orbit embraces the primitive nebular centre of planetary inertia ($\sqrt{\Sigma\mu\rho^2 \div \Sigma\mu} = \rho_6$). The subsidence *vis viva* of Jupiter is to that of Saturn as æthereal *vis viva* at Sun's surface is to that at Kant's limit.

20_1. The predominating planetary influence of Jupiter, the tendency to grouping in pairs, the probability of segregation at the centre of the inter-asteroidal belt while Mercury and Mars were still zodiacal rings, mutual equilibrating activity and the influence of "subsidence" as taught by Herschel (Outlines of Astronomy, sec. 872), are shown by (20) and by the deduced equation $m_5 \times (m_1 + m_4) = (m_2 + m_3) \times (m_7 + m_8)$. It will be seen that this relationship is independent of any influence of the chief centre of nucleation (m_0) and the nebular centre of planetary inertia (m_6). The relations of subsidence *vis viva* among the groups introduce the ratio of oscillating æthereal volume (V_l) to corresponding subsidence-volume (V_μ).

21_1. The subdivisions of the foregoing groups show the influence of reciprocal harmonic *vis viva*. At the primitive centre of condensation, the subsidence *vis viva* of Venus is to that of Earth, as the product of Venus's mass by æthereal *vis viva* in Earth's orbit, is to the product of Earth's mass by æthereal *vis viva* in the orbit of Venus. We may also state 21 under the following form:

$$m_2^2 : m_3^2 :: \mu v_3^2 : \mu v_2^2.$$

This shows that the products of gravitating potential by ætherial orbital *vis viva*, for the two central planets of the dense belt, are equal.

22_1. In the segregation of the outer zodiacal rings of the dense belt, the reciprocity is that of simple æthereal orbital *vis viva*, the subsi-

dence *vis viva* of Mercury bearing the same ratio to that of Mars, as æthereal *vis viva* in the orbit of Mars bears to æthereal *vis viva* in Mercury's orbit.

23_1. In the segregation of the two outer rings of our stellar system, the same reciprocity is shown, the subsidence *vis viva* of Uranus bearing the same ratio to that of Neptune, as æthereal *vis viva* in Neptune's orbit bears to æthereal *vis viva* in the orbit of Uranus. Solving the foregoing proportions (17–23), we get harmonic values for the several planetary masses which agree very closely with the latest astronomical estimates, as is shown by the following table:

	Harmonic.	Astronomical.	Computers.	
$m_0 \div m_1$	4507467	4480040	Encke.	24
$m_0 \div m_2$	385313	385395	Newcomb-Leverrier.	25
$m_0 \div m_3$	327704	326800	Newcomb.	26
$m_0 \div m_4$	2854790	2848277	Hall.	27
$m_0 \div m_5$	1056·27	1050	Leverrier.	28
$m_0 \div m_6$	3490·04	3482	Hall.	29
$m_0 \div m_7$	22530	22800 $\pm$ 100	Newcomb.	30
$m_0 \div m_8$	19403	19380 $\pm$ 70	Newcomb.	31

In the ordinary astronomical tables of planetary elements, the planetary masses in the dense belt are deduced from their ratio to Earth's mass, on the old hypothesis that $m_0 \div m_3 = 354936$, while the extra-asteroidal masses are deduced from their ratio to Jupiter's mass. To remedy this inconsistency and at the same time to give values which are accordant with modern investigations, I have made such changes in the "Astronomical" column as are required by Newcomb's estimate of Earth's mass, which represents the greatest amount of labor, practical experience and mathematical ability that have ever been directed toward the solution of the problem. It is, moreover, within the limits of uncertainty which are still left by the discussions, so far as yet published, of the last transits of Venus.

The greatest difficulties in the astronomical estimation of mass, are presented by Mercury and Venus, on account of the absence of any known satellites. The two latest estimates for Venus are those of Leverrier ($m_0 \div m_2 = 379479$) and Newcomb (391310). The close agreement of the harmonic estimate with the mean of these two estimates, is, to say the least, very curious and interesting. The precise accordance in the cases of Uranus and Neptune, the closeness of agree-

ment in the cases of Earth and Mars, and the fact that each of the harmonic estimates is within the limits of probable error, are also satisfactory, especially when we consider that no allowance is made in the theoretical column for possible modifications by secondary harmonies, dependent upon planetary perturbations and orbital eccentricity, which are important elements in astronomical computation.

The simplicity of the principles which have led to the discovery of these relations may well encourage further investigations in the same field. The application of some of the higher branches of mathematical analysis and especially of spherical harmonics may, perhaps, lead to results which will not only be interesting, but will also be doubly valuable, inasmuch as theoretical anticipations can be readily tested by practical observation.

Bode's law, notwithstanding its failure in the case of Neptune, may, perhaps, be a partial expression of a more extensive and more general law. Indeed within the solar system, planetary or belt positions are nearly represented by the series 4, 7, 10, 16, 28, 52, 100, 196, 292, in which there are two equal intervals at the outer limit as well as two at the inner limit and the intermediate positions follow Bode's progression.

One of the simplest forms of cumulative harmonic influence is based upon simple harmonic motion, in which synchronous oscillations introduce the ratio $\pi \div 2$. If we take Earth and Neptune at their respective present points of incipient subsidence (secular aphelion) we find that the first and second harmonic submultiples of Earth's position are in the secular orbits of Venus and Mercury, the first multiple is in the orbit of Mars, and the fifth multiple is in the orbit of Saturn; the first submultiple of Neptune's position is in the orbit of Uranus, and the fourth in the orbit of Jupiter; the geometric mean between the second and third submultiples of Neptune is in the orbit of Saturn, while the geometric mean between the third and fourth multiples of Earth is in the orbit of Jupiter.

If we take the cumulative harmonic influence, which begins with Sun's semidiameter, with $\frac{\pi}{2}$ of the Kantian diameter, or the Kantian semicircumference, as the second term, the first five terms of the progression are $\rho_\circ$, $\pi L\rho_\circ$, $\pi^2 L^2\rho_\circ$, $\pi^3 L^3\rho_\circ$, $\pi^4 L^4\rho_\circ$. The second term is in the belt of greatest condensation; the third bears the same ratio to the solar modulus of light as $\rho_\circ$ to ρ_k; the fourth is π times the solar modulus of light; the fifth is in a region of predominating stellar influence.

If we determine, by the method of least squares, the law of planetary progression, we find that it is suggestive of harmonic paraboloidal subsidence. Suppose Sun to be in the focus of a paraboloid of revolution, with a directrix plane at $\frac{\rho_0}{3}$ and a vertex at $\frac{\rho_0}{6}$. Suppose the nearest fixed star (presumably α Centauri) to be in the axis of the same paraboloid. Take 39 numerical abscissas of the form $A_n\xi\eta^n\zeta^{n^2}$, with $A_0 = \xi = \frac{1}{6}$, $A_{19} = \frac{1}{3}\ L\rho_0$, $A_{38} = LM = \pi^2 L^4\rho_0$. One third of the abscissas $(A_0 \cdot\cdot A_{12})$ are within the solar photosphere; one third $(A_{13} \cdot\cdot A_{25})$ are extra-solar and inter-asteroidal; one third $A_{26} \cdot\cdot A_{38}$ are extra-asteroidal and inter-stellar. The next abscissa (A_{20}) is in a region of predominating stellar influence, approximately, and *perhaps* exactly, in the locus of α Centauri.

The twenty-seven extra-solar and inter-stellar abscissas may also be divided into three equal suggestive groups, $A_{12} \cdot\cdot A_{20}$ being inter-planetary; $A_{21} \cdot\cdot A_{29}$ having significant planetary relations; $A_{30} \cdot\cdot A_{38}$ being extra-planetary. The middle group $(A_{21} \cdot\cdot A_{29})$ represents, respectively, $\frac{1}{2}$ Mercury, $\frac{1}{2}$ Venus, $\frac{3}{5}$ Earth, $\frac{3}{4}$ Mars, $\frac{4}{5}$ Asteroid, $\frac{6}{7}$ Jupiter, $\frac{6}{7}$ Saturn, $\frac{7}{8}$ Uranus, $\frac{7}{8}$ Neptune, the indicated loci being all within orbital limits. We find here, as in the Bodeian series, two equal numerators at the outer limit, where the harmonic mean of the two coefficients is unity, as well as two at the inner limit, where the harmonic mean is $\frac{1}{2}$. The coefficients $\frac{1}{2}, \frac{2}{3}$, etc., represent successive and progressive harmonic rupturing tendencies, inasmuch as particles falling toward a cosmic focus from a distance nr, would acquire the dissociative velocity, $\sqrt{2gr}$, at $\frac{n}{n+1}\ r$. The reciprocal character of the Saturnian and Neptunian coefficients furnishes an indication of such retrograde tendencies as we may naturally look for at the outer limits of a planetary system.

Although it is impossible, at present, to anticipate with certainty the precise way in which undiscovered harmonic influences will be manifested, it may be possible to show the probable existence of such influences and where to look for them. The tendency to make absolute any close approximation to simple numerical relations, which is found in Jupiter's satellites, should likewise often prevail in planetary motions. The number of such tendencies among the cosmical masses and positions is so great that it is difficult, for want of definite criteria, to judge of their relative importance. It may, perhaps, finally be found that they are all satisfied by adjustments of orbital eccentricity.

BACKWATER.

By C. H. PEABODY,
Assistant Professor of Applied Mechanics, Massachusetts Institute of Technology.

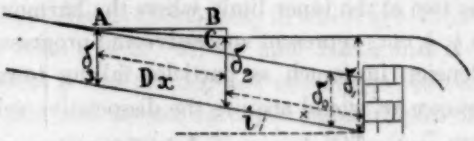
In Rankine's Steam Engine there is given the following equation for determining the curve of the backwater produced by a dam thrown across a channel of uniform width and declivity:

$$x = \frac{\delta_1 - \delta_2}{i} + \left(\frac{1}{i} - \frac{2}{f}\right)(\psi_1 - \psi_2)\,\delta_0\,;$$

in which x is the distance from the dam at which the water has the depth δ_2, δ_1 is the depth immediately above the dam, δ_0 is the original depth of the stream before the dam was introduced, i is the inclination of the bed and f is the coefficient of friction; φ is the following function of $r = \frac{\delta}{\delta_0}$:

$$\varphi = \int \frac{dr}{r^3 - 1} = -\tfrac{1}{6}\,\text{hyp. log.}\left\{1 + \frac{3r}{(r-1)^2}\right\} - \frac{1}{\sqrt{3}}\,\text{tan.}^{-1}\,\frac{2r+1}{\sqrt{3}}$$

The equation given may be derived in the following manner. In the figure let δ_2 represent the depth at the distance x from the dam,



and δ_3 the depth at the distance $x + \Delta x$. If A is the area of the cross-section of the stream and b the wetted perimeter, then the loss of head on account of friction is $\frac{fb\Delta x}{A} \cdot \frac{v^2}{2g}$, in which v is the mean velocity between A and B. Now there is a fall at the surface of the stream of $BC = h$, and since the velocity changes from v_3 at A to v_2 at B, there is an available head from that source of $\frac{v_3^2 - v_2^2}{2g}$, consequently

$$\frac{fb\Delta x}{A}\,\frac{v_2}{2g} = h + \frac{v_3^2 - v_2^2}{2g},$$

$$h = \frac{fb\Delta x}{A}\,\frac{v^2}{2g} - \frac{v_3^2 - v_2^2}{2g}.$$

Since the width remains constant the velocities are inversely as the depths, consequently

$$v_3^2 - v_2^2 = \frac{\delta_2^2 - \delta_3^2}{\delta_3^2} v_2^2,$$

and it is apparent from inspection of the figure that

$$h = \Delta x \sin. i - (\delta_2 - \delta_3).$$

Substituting these values in the equation above,

$$\Delta x \sin. i - (\delta_2 - \delta_3) = \frac{fb\Delta x}{A}\frac{v^2}{2g} - \frac{(\delta_2 - \delta_3)(\delta_2 + \delta_3)v_2^2}{\delta_3^2 \quad 2g},$$

$$\therefore \Delta x = \frac{1 - \dfrac{\delta_2 + \delta_3}{\delta_3^2}\dfrac{v_2^2}{2g}}{\sin. i - \dfrac{fb}{A}\dfrac{v^2}{2g}}(\delta_2 - \delta_3)$$

If A approaches B, Δx approaches dx and at the limit may be written dx; at the same time $\delta_2 - \delta_3$ becomes $d\delta = \delta_0\, d\left(\frac{\delta}{\delta_0}\right) = \delta_0\, dr$. For δ_3 and δ_2 may be written the variable δ, and for v_2, v. As an approximation i may replace sin. i, and $\frac{1}{\delta}$ may be used for $\frac{b}{A}$ if the stream is considerable wider than deep. Making these changes

$$dx = \frac{1 - \dfrac{2}{\delta}\dfrac{v^2}{2g}}{i - \dfrac{f}{\delta}\dfrac{v^2}{2g}}\delta_0\, dr.$$

Since the velocities are inversely as the depths $v = \frac{v_0\delta_0}{\delta}$. But before the stream was dammed the slope just overcame the friction, or

$$\sin. i = \frac{fb}{A}\frac{v_0^2}{2g} \quad \therefore \frac{v_0^2}{2g} = \frac{\delta_0 i}{f}.$$

Substituting for v

$$dx = \frac{1 - \dfrac{2i}{f}\dfrac{\delta_0^3}{\delta^3}}{i - i\dfrac{\delta_0^3}{\delta^3}}\delta_0\, dr,$$

$$dx = \frac{1}{i}\left(1 + \frac{1 - \dfrac{2i}{f}}{r^3 - 1}\right)\delta_0\, dr.$$

Integrating between the limits r_1 and r_2,

$$x = \frac{\delta_1 - \delta_2}{i} + \left(\frac{1}{i} - \frac{2}{f}\right)\left[\int_{r_2}^{r_1} \frac{dr}{r^3 - 1}\right]\delta_0,$$

the equation at the head of the article.

Rankine also gives the following approximate integration:

$$\varphi = \int \frac{dr}{r^3 - 1} = \int \frac{dr}{r^3} + \int \frac{dr}{r^6} + \int \frac{dr}{r^9} + \text{etc.}$$

$$\therefore \quad \varphi = -\frac{1}{2r^2} - \frac{1}{5r^5} - \frac{1}{8r^8} - \text{etc.}$$

and derives from it a table which much reduces the labor of calculation.

r	$-\varphi$	r	$-\varphi$
1·0	∞	1·8	·166
1·1	·680	1·9	·147
1·2	·480	2·0	·132
1·3	·376	2·2	·107
1·4	·304	2·4	·089
1·5	·255	2·6	·076
1·6	·218	2·8	·065
1·7	·189	3·0	·056

In the Steam Engine the values for φ are given with positive sign; also the results of the integration of $\int \frac{dr}{r^3 - 1}$, both exact and approximate, have the positive sign, which is evidently an error.

The value of $\frac{2}{f}$ is given as 264.

Attention is called to the fact that the first member of the right hand side of the equation deduced above, is the distance back of the weir at which the depth δ_2 would occur if the surface of the water were horizontal. If the slope is 1 in 264, that is if $\frac{2}{f} = \frac{1}{i}$, the second term vanishes. For a greater declivity it becomes negative, showing a rise of water toward the weir.

THE PANAMA INTEROCEANIC CANAL.

By CHARLES COLNÉ,
Secretary of the American Committee of the Universal Interoceanic Panama Canal Company.

[Read at a Special Meeting of the FRANKLIN INSTITUTE, Wednesday, October 22, 1884.]

MR. HECTOR ORR in the chair.

MR. COLNÉ:—The question of shortening communication between Europe, the United States and the West Coast of Central and South America by means of an artificial waterway has attracted, for years, the attention of many minds. Its vast importance to commerce and navigation was long ago felt; in this age of rapid transit it becomes a necessity. The advantages to be derived from such a means of communication can scarcely be computed, for past experience in similar routes has demonstrated that the most sanguine expectations have been met and even surpassed.

Many have been the projects, explorations upon explorations have been made, some of a very crude nature, but of late years valuable data have accumulated upon nearly all practicable passages. This question, like many important ones is not new. It has taken many years, however, to bring it to a practical solution. It has required many researches, it has cost much labor and in several instances sacrifices of life.

Many of us will remember the recent agitation by the press and by discussions in our public halls of the best means to unite the waters of the Pacific Ocean with those of the Atlantic. This, to the public at large, was rather a new question. History tells us, however, that over three and half centuries ago the proposition of cutting a waterway across the American Isthmus had already assumed importance.

Vasco Nuñez de Balboa, in 1513, having taken possession of the Pacific Ocean, bethought himself of effecting a passage through the rivers of Darien, but his death, a short time afterwards, put a stop to this project.

In 1523, ten years afterwards, Fernando Cortez, then master of Mexico, proposed a waterway through the Isthmus of Tehuantepec. He employed Gonzalo Sandoval to make a very careful survey of the land. Even when the Emperor Charles V withdrew the Government of Mexico from his hands, he nevertheless continued to urge his project for a maritime canal at the place he had selected. But as the Emperor at that time was more engrossed with the, to him, more

important question of getting revenue from New Spain, the idea of spending money for the benefit of that country was altogether unwelcome. To this proposition he remained as indifferent as he had been before to that made to him by Angel Saavedra, in 1520, to adopt the idea of Balboa to cut the Darien Isthmus. It is a remarkable fact that these two first proposed routes for interoceanic canals should represent the two extreme points where crossings could be effected.

In a document submitted to the Portuguese Congress under the title "The Cutting of the Isthmus of Panama in the Sixteenth Century," by Pereira de Païva, it is stated that since 1550 four different routes had been proposed by a celebrated Portuguese navigator, Antonio Galvao, who had published a book entitled "A treatise upon the sundry and circuitous ways by which pepper and spices have been sent, and upon ancient and modern discoveries made up to the year 1550." In this Galvao states that a maritime canal can be cut in four different places. First, between the Gulf of Uraba and the Gulf of San Miguel; second, through the Isthmus of Panama; third, along the San Juan, through Lake Nicaragua; and fourth, through the Mexican Isthmus. It would then seem that the principal routes were already known before the end of the sixteenth century. The surveys, however, up to this time were far from being thorough, they simply gave general ideas of the routes to follow. Many were the difficulties in the way of obtaining positive information, the country was totally unknown. Several explorers started out to get the desired information, but they all met with partial success, only. Among them were Morales, Meneses, Espinosa, Pedrarias and Andagoya. Nothing definite was ever brought back by any of them.

The seventeenth century was rather indifferent to the question of interoceanic communication. Towards the end of the eighteenth century the idea was again revived. England, then, as now, alive to any question of self-interest, thought it would be of great value to her if she could succeed in controlling a passage from ocean to ocean. At this period a passage through a canal was not so much thought of as the possibility of making rivers available for this purpose. Nicaragua was looked upon as offering these advantages. So in 1778 by methods not unlike those in use by her at the present day, she sent Nelson on an expedition against Nicaragua, in order to take possession of the territory. This expedition, however, was not numbered among the

victories of the British; it proved to be very disastrous, and Nelson nearly lost his life.

It may be said that in 1780 the first technical explorations started under the orders of Charles III, King of Spain, with the French engineer, Martin de la Bastide as leader, and the Spanish engineer, Manoel Galistro, for the purpose of having a canal cut through the Isthmus of Panama. On their return to Spain they found the country plunged into political questions arising out of the French revolution, the death of Charles III taking place soon afterwards, nothing came of this effort. The Viceroy of New Spain, Antonio de Bucareli, in the meantime had shown a favorable disposition by having several surveys made by engineers Corral and Cramer.

At the beginning of the present century, the celebrated Humboldt, after having been personally upon the spot, advocated, in 1804, with Admiral Fitz Roy, the Darien route. These well known names carried many partizans with them, and thus, for the first three quarters of this century, the Darien Isthmus has been the stumbling-block in the way of accomplishing interoceanic communication. It took the two very laborious surveys of Messrs. Wyse and Reclus in 1877 to remove the Darien route out of the way, and it was then discovered that the projects had been based upon erroneous suppositions.

In 1814 the Spanish Cortes passed a resolution ordering the Viceroy of New Spain to undertake the cutting of a canal on the Isthmus of Tehuantepec. Mexico having shortly afterward, become an independent State the burden of this work fell upon the new Government. In 1821 General Orbegoso surveyed the line, and in 1842, under Santa Anna, Don José de Garay, after having obtained a concession for a canal, continued the surveys. His son, Don Francisco de Garay came to Paris to advocate this line before the International Commission of 1879.

Napoleon Garella, a French mining engineer, first gave positive data upon the Panama Isthmus, for the purpose of building a railroad or a canal. This project found favor with the French army engineer corps, and received their endorsement.

The two route-surveys were completed in 1844. A French company paid the expenses of the survey and decided to build a railroad. Through delays and the untoward events of the French Revolution of 1848 the proposition fell through. The concession having expired, an American company obtained a new one, and built the Panama rail-

road of the present day. Thus do we owe to an American enterprise the possibility of a successful crossing of this heretofore almost impassable strip of land. To my friend, the late Col. G. M. Totten, we owe the successful accomplishment of this work. His indefatigable perseverance and tenacity conquered the many difficulties in his way. He lived in New York, up to last May, to a ripe old age, respected and loved by all. At the time of his death he held the position of consulting engineer of the American Committee of the Panama Canal Company in New York. Philadelphia also had among her honored citizens up to a short time ago, a worthy co-laborer of Col. Totten, Engineer J. C. Trautwine. To both of these men the California gold seekers of 1848 and '49 owe a debt of gratitude, for having lightened their tedious way across the Isthmus. Among the directors of the Panama Railroad may be found the name of Mr. Theod. J. de Sabla, son of Mr. de Sabla, who patronized and proposed the first railway communication across the Isthmus. He has been a resident of New York for many years.

In 1850 Gen. Barnard, of the Army Engineer Corps, after returning from Tehuantepec, where he had been surveying a line for a railroad, gave his opinion that this Isthmus was the most unfavorable spot for a crossing between the two oceans.

Honduras was then thought to have many advantages. The surveys of Squiers, Trautwine and Jeffer dispelled such an idea. Nicaragua was then taken up; the San Juan River, the great lake and the low altitude of the land were thought to be favorable conditions. Engineers Childs and Fay, after having made technical surveys, reported favorably. For thirty years this route remained in favor, and to the present day has some adherents still. A French engineer, Felix Belly, and an American engineer, Crossman, also explored the Nicaragua line, the latter lost his life trying to cross the bar at Greytown.

In this country the route advocated by Humboldt and Fitz Roy through the Isthmus of Darien had many adherents. Among them Mr. F. M. Kelly, a gentleman now living in New York, spent large sums of money in defraying the expenses of several surveying parties in that section. The Trautwine expedition in 1852; the Lane and Kennish expedition in 1853, under his auspices came back, however, without bringing a satisfactory knowledge of the Isthmus. Dr. Cullen, a strong advocate of this route, stated then that he thought a low valley existed through which the Caledonian Bay could be reached

by the way of the Savannah. This confidence induced many new explorers to take the field, but they were nearly all unfortunate.

Patterson and his Scotchmen died in the neighborhood of the Lara and the Savannah. The American engineer, Strain, started for the Caledonian Bay, but lost his way, his instruments and provisions, then mistook the Chucunaque for the Savannah. For days and days he and his companions, wandered through a merciless and impenetrable forest, seventeen of his men died; Strain himself, in consequence of the terrible hardships he had endured in that unfortunate expedition, died on landing in the United States.

In 1853, Gisborne, driven away by the natives of the country, did not bring back anything of value. Prevost's men were killed by the Indians. From all these expeditions nothing but indefinite and contradictory information was brought back.

In 1858, General Michler, of the Engineer Corps, took up the surveys of Trautwine and recommended a line running through the valleys of the Truando and Atrato rivers.

In 1870, our Government, finding none but conflicting reports from previous surveys, decided to have a thorough and new one made for every proposed route. With a praiseworthy liberality, ships, men and treasure were put at the disposal of the commanders of these expeditions. Commodore Shufeldt went to the Isthmus of Tehuantepec, Commanders Hatfield and Lull to Nicaragua, Lull continuing his researches to the Isthmuses of Panama, Darien and a small part of Cauca, were also explored by Commander Selfridge and Lieutenant Collins. It took three years to complete these explorations.

In 1871, the first Geographical Congress took place at Antwerp. General Heine, an American, advocated Mr. Gogorza's project, who with Lacharme were said to have found an exceptionally favorable route on the Darien Isthmus through the rivers Tuyra, Atrato and its affluent the Caquirri. At this meeting of the Congress a resolution was adopted recommending attention to Mr. Gogorza's route. At the next meeting his project again received favorable consideration.

In 1875, however, Mr. Ferd. de Lesseps expressed an opinion that a great mistake had been made in proposing none but canals with locks and strongly urged the adoption of a sea-level canal, like the Suez, doing away with locks. This he maintained was the only kind of canal capable of meeting the requirements of modern commerce removing all delays and obstacles inherent to locks. This new idea after a

thorough discussion caused the Congress to adopt a resolution recommending a canal "offering the greatest facilities of access and circulation." Since the proposition had such a novel character from the old settled ideas of canal, this Congress naturally conservative did not think it prudent at this time to go any further. This apparently harmless resolution, however, lead the Geographical Society to inquire into the matter of interoceanic canal with new ideas. It was soon discovered that the geography of the Isthmus was quite incomplete in several parts, though many explorations had already been made. For the lack of sufficient information no recommendation could be made, and to obtain such information much more money would be required than was at the disposal of the Society. A committee was appointed, with Mr. de Lesseps as chairman, to continue the researches. While they were at work Lieutenant Wyse and General Türr succeeded in forming a private company to furnish the money to continue the exploration and surveys. During the same year an expedition was fitted out under the command of Lieutenant Wyse. After many painful journeys and sufferings the party succeeded in going over the supposed favorable route of Gogorza, but no special advantages were discovered. Messrs. Wyse and Reclus, the latter also a lieutenant in the French navy, thought that a better route could be found further west between the Tuyra and the Acanti bay. The rainy season having set in operations had to be suspended. Three members of this expedition Messrs. Bixio, Brooks and Musso, died during this laborious work. Messrs. Wyse, Reclus, Gerster and Lacharme, only returning. The following year the work was again taken up. While Lieutenant Reclus finished up the surveys of the Tuyra-Acanti route, Lieutenant Wyse explored the San Blas region and the Panama Isthmus was again gone over. The void left by former explorers was now filled and complete information obtained.

Thus through private efforts the long wanted and important technical data were supplied, and also through private efforts did Mr. de Lesseps obtain the first capital for the prosecution of the work on the Panama Interoceanic Canal, an enterprise of vast magnitude and of world-wide importance. Surely a man able to command such confidence, repeated three times since, in the shape of new and large subscriptions, cannot be the deceiver which a part of the press of this country has represented him to be. A nation which shows such confidence in the man, as France has, must certainly have good reasons for it.

France has not only furnished the larger part of the capital, but she also has furnished the brain for carrying out a work which has attracted the attention of the whole world for so long a time. Instead of deriding her let America praise and encourage her, for we are the nation that will derive the greatest advantages from such a work.

If an enterprise has merit to commend it to capitalists, what need is there to appeal to government aid as has lately been done here by persons seeking to open another interoceanic canal? It is not compatible with the spirit of our government to be paternal, the people appoint their representatives, not rulers. If the people of this country want a second canal and they think there will be sufficient business for it, they will not be slow in manifesting their sentiments on that question to their representatives. In the meantime if foreign capital is willing to open a canal let us not make a laughing stock of ourselves by making a causeless war upon, I may say, such a humanitarian enterprise, Americans in general are too fond of fair play to countenance anything having the flavor of unfounded prejudice.

On the eve of seeing a great waterway opened to the commerce of the world, it may not be uninteresting to look back and see what makeshifts trade has had to resort to for transporting goods in former times.

When Pizarro had conquered the empire of the Incas, and Peru had become one of the richest jewels of the Spanish crown, trade with the mother country naturally increased wonderfully.

How to avoid the long and dangerous navigation through the Straits of Magellan, or around Cape Horn, became a question of much importance. It was quite natural that the narrow strip of land discovered by Balboa should be looked to for a solution of these obstacles and as offering a rapid and sure passage. And since this route could be shut out from use by any but the Spaniards, to the exclusion of all heretics, it had special merits in the eyes of this fanatical people. The plan adopted was this. It was agreed that every year a fleet of galleons should start at a given time from Spain for the east coast of the Isthmus, and at the same time another fleet should leave Peru for the western coast. Between the two landing places a road was to be opened overland to transport from ship to ship the valuable cargoes and passengers of these fleets. What point should be selected over this Isthmus extending over 1,500 miles for the opening of a road? Even at this early date the Isthmus had been thoroughly explored, and had it not been that the records of the surveys of the wonderful

Adelantados (Governors) had remained in the secret archives of the Spanish government nothing would have been necessary to rediscover.

The route selected ran over the ground which has since been recognized, by thorough surveys, from Darien to Tehuantepec, to be the most suitable. Nothing could induce the "Conquistadores" to adopt any other line than that which was subsequently selected for the Panama railroad. The Panama canal, the colaborer of the railroad, will also follow substantially the old route of the Spaniards. The roads adopted for this primitive Isthmian traffic started from nearly the same points on the eastern coast and ended at Panama.

When Morgan, the fillibuster, in 1670 invaded the country, the road was made up of two pathways, one starting on the Atlantic from Porto Bello the other from Chagres, both ending in Panama, thus forming an open angle with Panama at the Summit.

From Porto Bello a mule-path wound its way through the forest, narrow, abrupt following hills and valleys, paved, however, in parts where the soil was too marshy, passing through and stopping at a few settlements, Pequeni being the principal one, where mules were changed. By this route were sent, on muleback all the dispatches, the gold and silver bars, from Peru, light merchandise and the mercury, then monopolized by the Viceroy of Peru, which was such an essential material for the rich mines of that country. This route was the rapid transit of the day.

From Chagres to Cruces the route was by way of the river. Large flat boats, sixty feet long and twenty-five feet wide, ran up and down these waters. Upon these boats all the heavy and bulky merchandise was loaded, and also the unfortunate negroes the Genoese merchants were sending to the mines of Potosi "by and under the authority of court." When Cruces was reached, the river not being navigable beyond this point, goods were unloaded and stored in warehouses. Although but a distance of twenty-two miles remained to reach Panama, all merchandise had to be transported there through narrow paths on muleback. To supply the wants of the traffic of these two roads no less than two thousand mules were required. These two roads were so impenetrable and so little known that at the time the freebooter Morgan made his dastardly descent upon Panama, among his twenty-two hundred French and English followers none were found capable to guide the expedition, although many of them

were well acquainted with the coast. He had to go to the Island of Saint Catherine where he found two convicts whom he set free and they consented to guide him. At no time during the Spanish rule does it ever appear that any better means of communication existed than a mule-path. It took Morgan nine days to go across and reach Panama. After the separation of the Spanish colonies from the mother country the necessity of intercourse between them having ceased, the Isthmus route was forgotten more than ever, and traffic between Europe and the Pacific coast took the Cape Horn route again. This old Isthmian road might have remained forgotten to this day had it not been that the discovery of gold in 1848, in California, gave a new and wonderful impetus to travel across the Isthmus. Porto Bello and Chagres, silent for so many years again became alive with surging and eager crowds of gold seekers, landing from constantly arriving ships. Bold adventurers pushed through the forest, but the vigorous growth of the climate had obliterated all traces of the former pathways with the exception of the few paved places in the marshes. With the eagerness the gold seeker displays in all countries these indomitable men finally cut their way through to Panama. This road having become an absolute necessity to our Pacific coast, it was not long before our people with their well-known pioneer spirit and enterprise completed the railroad which was then in process of construction across the Isthmus. The Panama Railroad now carries merchandise and passengers through in a few hours, not so rapidly as some of our roads in the United States perhaps, but compared to the old time modes of travel this railway is a vast improvement. Since the canal work has been going on the capacity of this road has been wonderfully increased.

We have had the mule-path with its discomforts, slowness and impediments, then the railway for the transportation of light merchandise and passengers.

There remains a desideradum for the cheap transportation of heavy and bulky merchandise in a rapid and uninterrupted manner. The Panama canal will fill these conditions.

HISTORY OF THE PANAMA CANAL.

In 1879 Count Ferdinand de Lesseps made an appeal to the several nations to send delegates to a proposed Congress to meet in Paris and

deliberate upon the different routes proposed for interoceanic communication between the Atlantic and Pacific Oceans.

On the 15th of May, of that year, pursuant to his call, this Congress met in Paris for organization. The following countries sent representatives: Germany, 1; England, 6; Austria-Hungary, 2; Belgium, 6; China, 1; Costa Rica, 1; Spain, 5; United States, 11; United States of Columbia, 4; Guatamala, 1; Hawai, 1; Holland, 6; Italy, 3; Mexico, 1; Nicaragua, 1; Portugal, 2; Norway, 1; Russia, 2; San Salvador, 2; Sweden, 1, and Switzerland, 4. France was also represented, as well as the Colonies of Algiers and Martinique—Peru, owing to the war then raging did not send any delegates. Among the French representatives, 74 in number, 4 were from Scientific Institutions, 8 from Chambers of Commerce, 25 from Geographical Societies, 4 from the Diplomatic Corps, 23 Engineers, 6 from the Navy or Navigation Companies, and 4 Mining Engineers.

Among the foreign delegates, 61 in number, 21 were Engineers, 1 Mining Engineer, 7 from Chambers of Commerce, 12 from Geographical Societies, 11 Foreign Diplomatic Representatives, 1 Army Officer, 2 from Scientific Societies, and 6 from the Navy.

Mr. Ferdinand de Lesseps was elected President; Rear Admiral Daniel Ammen, from the United States; Sir John Stokes, from England, Vice-Admiral Likhatchof, from Russia; Commander Negri Cristoforo, from Italy, and Colonel Coello, from Spain, as Vice-Presidents; Mr. Henri Bionne, from France, General Secretary.

To facilitate the work of the Congress and to dispatch business "à l'americaine," as Mr. de Lesseps expressed it, five commissions were appointed. The first, on "Statistics," or probable business of the canal, and the participation of each nation. The second, on "Economical and Commercial Questions," the advantages each nation would derive from the canal, etc. The third, on "Navigation," the kind of ships that would be likely to go through the canal, the influence of the canal on future ships, the prevailing winds and currents, the climate, meteorology, and their effect on materials, etc. The fourth, and most important, on "Technological Questions:" Expenses for Construction, for operating, for repairs, facility and security of navigation.

This commission was divided into two sub-commissions, one to discuss and decide upon the route to be adopted, the other to make estimates of cost. The work of these two commissions was, in fact, to guide the deliberations of the Congress in regard to the route and the

style of canal to be adopted. The fifth commission was to determine upon the "ways and means" for operating the canal and the probable revenue. The fourth commission virtually decided the question of the Interoceanic Canal. It was composed of 42 members: 29 Engineers, 3 Mining Engineers, 2 Contractors, 2 members of Scientific Institutions, 2 members of Geographical Societies, 2 Officers of the Navy, 1 Officer of the Army, and one Foreign Minister.

The United States had a representation of 11 members: 2 Engineers, 2 Officers of the Navy, 2 members of Geographical Societies, 4 members of Chambers of Commerce, 1 member of a Scientific Society. Three of these representatives were members of the Technological Commission.

Each of the commissions, after full and free debates, had reports prepared by well-qualified persons, upon the different questions referred to them. These reports are replete with information, and are founded upon data furnished by competent persons from all nations. Each of these reports was submitted to the general meeting, and formed a basis for deliberations. The persons advocating the different canal schemes were afforded opportunities to appear before these commissions and explain their proposed routes.

The meetings of the Congress lasted from the 15th to the 29th of May, 1879. On the last day the following resolution was adopted:

"Congress believes that the cutting of an inter-oceanic canal, with a constant level, so desirable for the interest of commerce and navigation, is possible; and that this maritime canal, to meet the indispensable facilities of access and utility which a passage of this kind should offer before all, shall be by the way of Limon Bay to Panama."

This resolution was adopted by the following vote, out of 98 members present:

Abstentions	12
Nays	8
Yeas	78
	98

Many of the absentees were persons who took no part whatever in the discussions and deliberations of the Congress.

It may, therefore, be said with safety, that with such an array of eminent men, experienced engineers, navigators, merchants, contractors and geographers, this decision has not been reached without mature

deliberation and a sufficient knowledge of the advantages and disadvantages of the different routes proposed.

Many projects were submitted, such as the route by Tehuantepec, by Mr. de Garay; the Nicaragua route, by Commander Lull and Mr. Menocal, with a modified project by Blanchet; the San Blas route of Mr. Kelley; the route by the Atrato and the Napipi, by Commander Selfridge. Mr. de Puydt also sent a communication regarding a route through Darien, starting from Puerto Escondido, to the Tuyra river, but for want of reliable data this route was put aside. The Panama route was presented by Lieutenants Wyse and Reclus.

After full and long discussions, but two routes were found to have sufficient merits for discussion—the Nicaragua and the Panama routes. It having been decided, however, that a canal with locks did not offer the advantages of a quick and unimpeded passage, it was finally cast aside and the sea-level route, without locks, tunnels, or any other impediments to navigation—the Panama route—was adopted. The only delay in transit—if such it can be called—that will be experienced in going through the Panama Canal will be the tide-lock at its mouth on the Panama side.

In the face of the decision of this Congress, composed as it was of men selected with the proper knowledge of the questions to be decided, our country being represented by well-qualified and well-known gentlemen, it does not seem reasonable that the voice of a few dissenters, whose interest lies in another direction, should have the precedence over such a majority of men of national reputation. The canal route has been selected, Mr. de Lesseps has organized his company, he has obtained the necessary capital for going on with the works, and, as Capt. Eads terms it, in his testimony before Congress, at Washington, "Mr. de Lesseps would belie his whole previous history if he did not push that work with all the energy he is capable of." A man who has built the Suez Canal in the face of the difficulties he had to encounter repeatedly, who with his well-known persistence has conquered them all, and has succeeded in giving to the world one of the greatest achievements of the age, can certainly be trusted to build the Panama Canal. Capitalists and the people have shown their faith in him by aiding him liberally with their money. Those who had faith in Mr. de Lesseps while he was struggling with the Suez enterprise have not lost faith in him yet; they have again come forward with their money to help him to build a new and more important canal. We, in the

United States, are to derive the greatest advantages of all the nations from the opening of such a canal; if we do not give it financial aid, we should, at least, from dictates of self-interest, if not from higher motives, give it our encouragement and wish it godspeed. For every year that the opening of a canal is delayed, Captain Merry estimates that our California coast loses $13,000,000, and he thinks that a tonnage of more than 3,000,000 tons can be relied upon for transit. The canal is an admitted necessity.

DESCRIPTION OF THE CANAL.

The canal commences at Colon (Aspinwall), running up to Gatun and to Dos Hermanas in a very long curve, almost a straight line, starting at the sea level in low lands, reaching Dos Hermanas with an elevation of land to 20 feet, in a gradual ascent, at a distance of 9⅜ miles from Colon. From Dos Hermanas to Frijole, a distance of 17½ miles from its mouth, the canal reaches the latter point at an average elevation of 40 feet, with the exception of a hill between Buhio Soldado and Buena Vista, reaching a height of 165 feet. From Frijole to Mamei, a distance of 24 miles from the mouth the line makes a bend, and reaches Mamei, with an average elevation of 50 feet, with intervening hills reaching to heights of 85, 100 and 118 feet. From Mamei to Matachin, 27 miles from Colon, the canal makes another easy bend, the height of the land averaging 55 feet, excepting a hill near Matachin of 168 feet. The balance of the line to Panama is comparatively straight. From Matachin to Culebra, a distance of 34 miles, the land becomes more undulating, with a series of hills reaching altitudes from 100 to 240 feet, and at the Culebra, reaching the highest point on the line, 330 feet.

From this altitude at Culebra the descent reaches to 30 feet at Rio Grande, a distance of 37 miles from Colon. From Rio Grande to La Boca the line again runs through low lands from 30 feet to the level of the ocean, having reached the distance of 42 miles from Colon. To reach the proper depth of water, dredging will be continued to a point near the Islands of Perico, being a distance of 46 miles from Colon.

The two ports, Colon and Panama, are to be improved so as to make the entrances easy of access. At Colon the port has already been improved very much; the channel has been dredged to the entrance of the Folks river, so as to allow the large American dredges to do their work in cutting the preliminary cut up to Gatun, where the Chagres

is reached. Quite a city has been built by the company between the Panama Railroad and the bay; it is known as Christopher Columbus. A large number of houses has been put up for quarters for the officers and employés of the Company. The principal street, Charles de Lesseps street, has a row of fine cottage houses for officers of the Company to live in. These houses were framed in the United States, taken down and again put up on the grounds of the new city. An extensive plot of ground has been filled in and reclaimed from the bay.

At the extremity of this land a wharf has been built, where the machinery, materials and food received for the Company will be landed. The Panama Railroad has a track extended to this wharf, so that all freight received can be sent at once to any point on the canal where works are going on.

Beyond the pier the filling has been continued so as to form a mole to protect ships while in the harbor from the effect of northern winds, which at times are quite violent and might cause damage and destruction to the shipping.

Dredging is now going on all over the bay, so as to give a sufficient depth of water at the wharf and at the entrance of the canal. Dredging is done with dredges belonging to the Canal Company. An American company has taken a contract for 39 millions cubic yards on this end up to Matachin, 27 miles from the mouth of the canal—the American Contracting and Dredging Company of New York. They have now three powerful dredges on the Isthmus built in the United States, and are building a fourth one in New York. The first cut made by these dredges has reached about three miles inland. A large number of workshops, storehouses, quarters, etc., have been erected in Colon, where machinery received from the United States and Europe is constantly being put up. The Company has also sub-offices in Colon. This place has become quite important, and the population has vastly increased. The Canal Company has rebuilt a wharf for their own use. At Matachin other workshops have been erected for putting up and repairing machinery. At Gamboa a station has been established with a view of the construction of the large dam at this point. At Culebra, the highest point on the line, work has been commenced; the dumping of earth will be much facilitated from the fact of there being lateral valleys at a lower level than the canal. At Corosal another large American Company, the Franco-American Trad-

ing Company, has just closed a new contract for dredging 10 millions of cubic yards. Ten dredges are to be employed in this work. The balance of the sections is all under way. At Panama a channel, 325 feet wide, is to be dug to low water near the Island of Perico, so that ships will be able to enter into the canal at any time. At the mouth (La Boca) of the canal a tide lock is to be built, so as to maintain at all times a sufficient depth of water for ships to go in and out of the canal. This has been found necessary, owing to the high rise and fall of the tides.

The Chagres river, being subject to heavy floods during the rainy season, it has been decided to build at Gamboa a large dam, to retain the waters and let them out gradually by lateral outlets or canals. In summer the Chagres river has a flow of 460 cubic feet, which reaches to 21,200 feet in winter, and in some instances of heavy flood it has attained 56,500 cubic feet per second.

To let such a body of water into the canal would be inevitable destruction. Lateral canals will consequently be cut to carry off these waters, varying in size from 27 feet at the bottom up to 131 feet near the sea. These will run off the freshet waters without lowering or raising their level. The dam is to be 492 feet at the base; between two hills, the cerro-Santa Cruz and the cerro-Obispo, it is to be 150 feet high. The waters retained in a valley above this dam will reach to 35 billion cubic feet. The lateral canal will have sufficient capacity to carry off, by a tunnel cut through solid rock on its right bank, 14,000 cubic feet per second. At a slight depth below the bed of the river a solid rock bottom has been discovered. It is proposed to erect the dam upon this rock foundation. The silt and gravel overlaying it will be removed and washed away by narrowing the river, and thereby increasing the current so as to give it sufficient force to remove these loose materials.

The dam will require about 9 millions of cubic yards of earth and rock to build it. There will be no difficulty, however, to procure such a large amount of excavation, for the neighboring hills to be removed will produce from 52 to 65 millions of cubic yards. The slopes down stream are to be very slight and protected with large stones. This precaution is taken so as to avoid the earth being carried away by freshets while the dam is in course of construction. It is not expected to make this dam water-tight at first; but, by throwing earth on the upper

side, it will gradually fill up the interstices between the stones and secure this object.

Such dams have often been constructed by our California engineers engaged in hydraulic gold mining enterprises, and have stood the test of years. The cost of this dam is estimated at $1,600,000, with all the accessory work; an overfall for the surplus waters will be provided in the construction. It is expected that the water above the dam will rise in winter to 95 feet above the level of the canal, or about 115 feet during the usual freshets of November. There are, however, exceptionally heavy freshets (seldom, however), when water may then rise to nearly 200 feet above the level of the water in the canal. In such a case, the lateral outlet will pour out 14,000 cubic feet per second, reducing the volume to three quarters of what it would be without the dam.

When the canal crosses rivers, as it does at a number of places, lateral canals or artificial channels will be excavated, pouring together again the waters of the rivers.

In the lowlands of the Rio Chagres and Rio Grande the canal is to be 72 feet at bottom, 164 feet at water level. In the section between San Pablo and Pedro Miguel 78 feet at bottom and 102 feet at water level; at the great Culebra cut, 72 feet at bottom and 100 feet at water level. The slopes are not yet definitely settled upon, but are approximately known.

Recent soundings have developed the fact that much less rock exists than had been anticipated. This is especially the case at the cut of the Culebra, where soundings have shown the materials to excavate to be composed of semi-soft rock of schistose formation, lying in horizontal layers, in dry earth. This favorable nature of the soil will produce a vast economy in the price of excavations.

The excavations necessary to complete the canal will be, for cutting the canal and the ports proper, 143 millons cubic yards, and for the lateral or derivation cuts, 13 millions cubic yards; together, a cubic measurement of 156 millions cubic yards. Of this amount, 52 millions will be excavated with dredges, the cheapest mode of working, and 104 millions cubic yards are dry excavation of earth and rock.

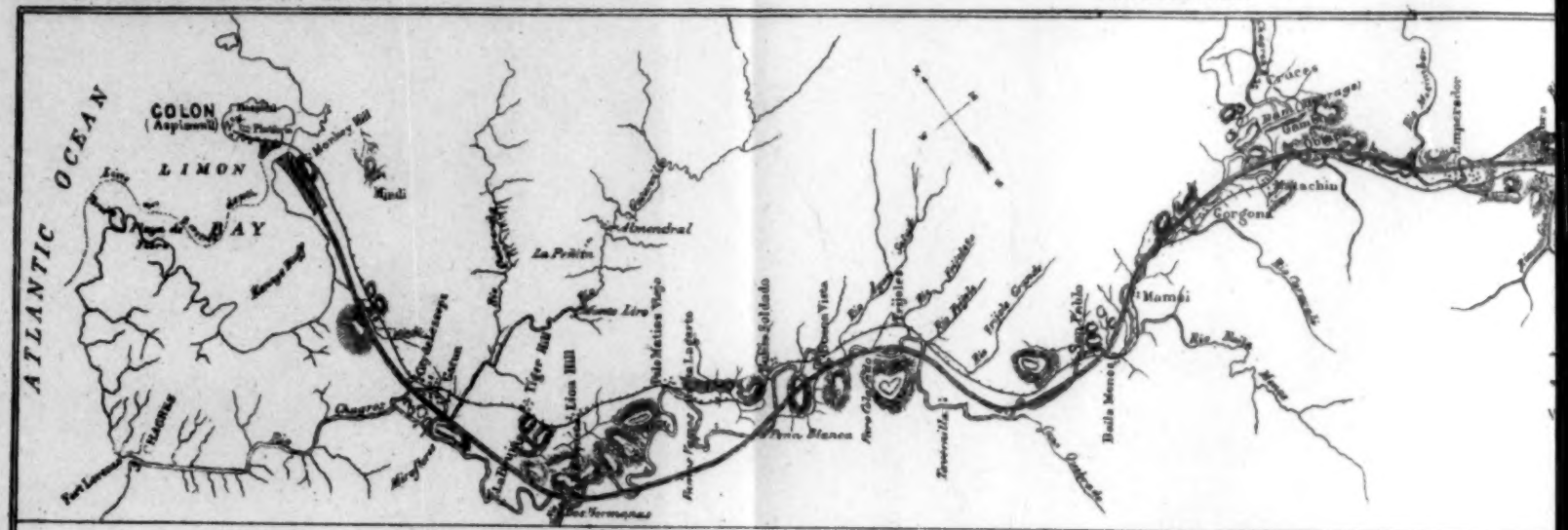
To faciltate traffic on the canal, since it is not possible for ships to cross each other in transit, it has been decided to dig a large basin or siding, 3 miles long, about midway of the canal, near Tabernilla.

The Canal Company has purchased a controlling number of shares

LOCATION OF THE PANAMA CANAL

and Situation of the Works in course of construction

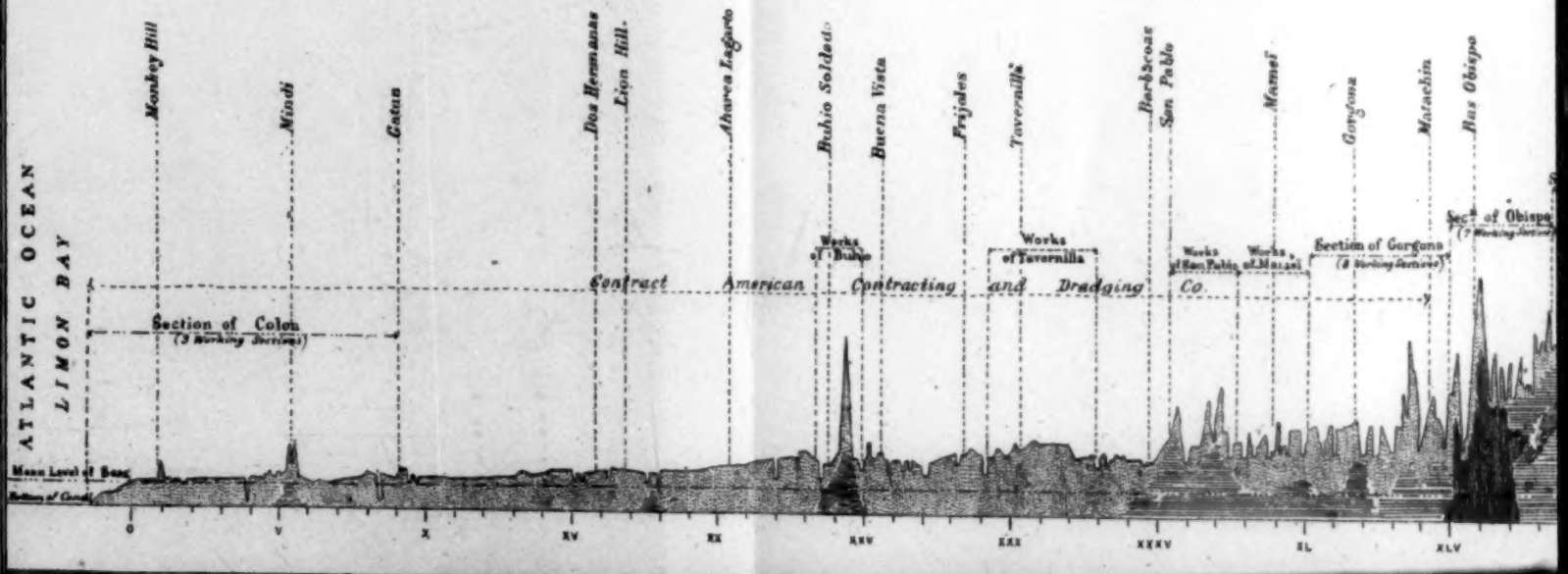
on June the 1st 1884



PROFILE ALONG THE AXIS OF THE CANAL

Heights amplified 100 times over lengths

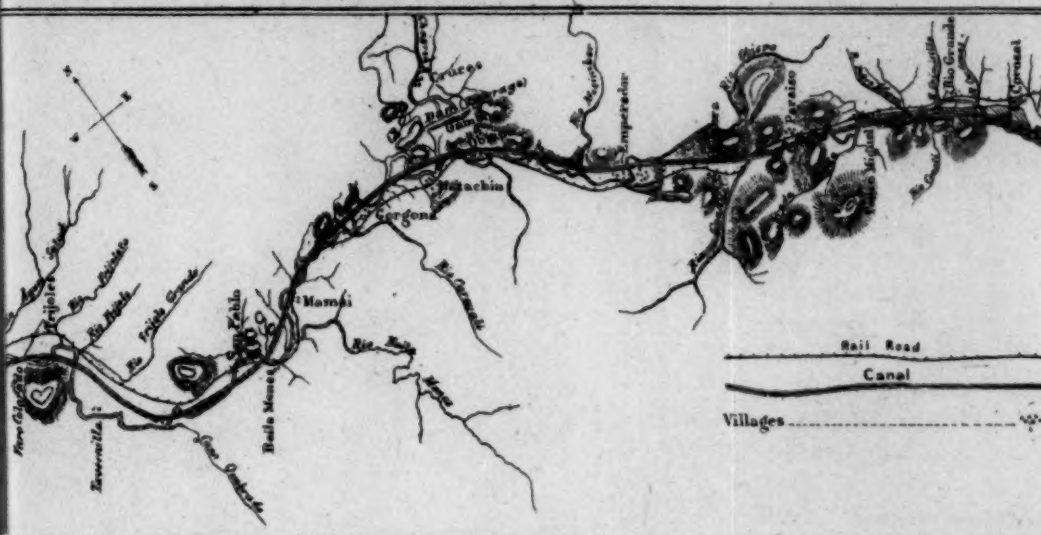
Scales { Heights / Lengths }



OCATION OF THE PANAMA CANAL

and Situation of the Works in course of construction

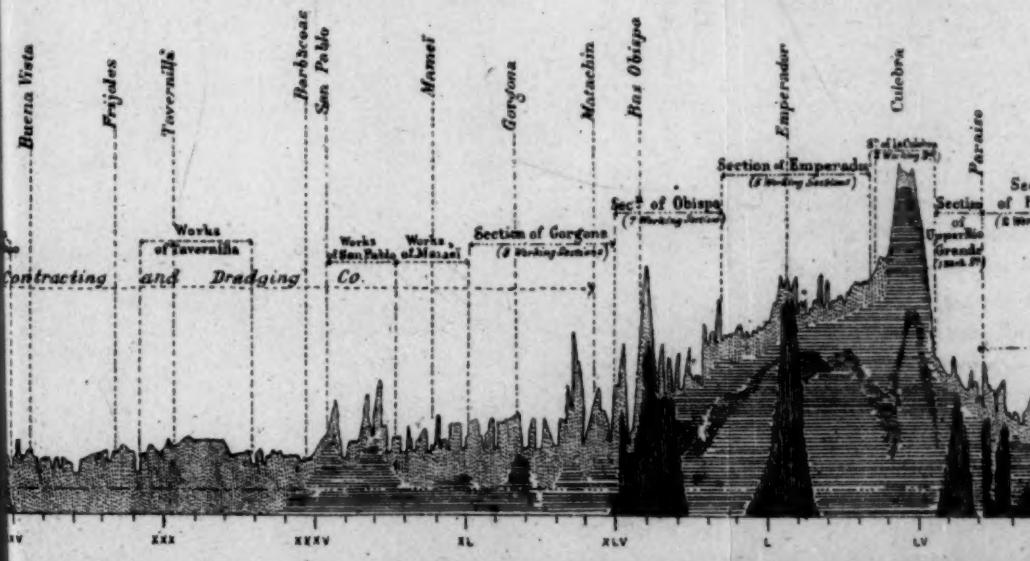
on June the 1st 1884

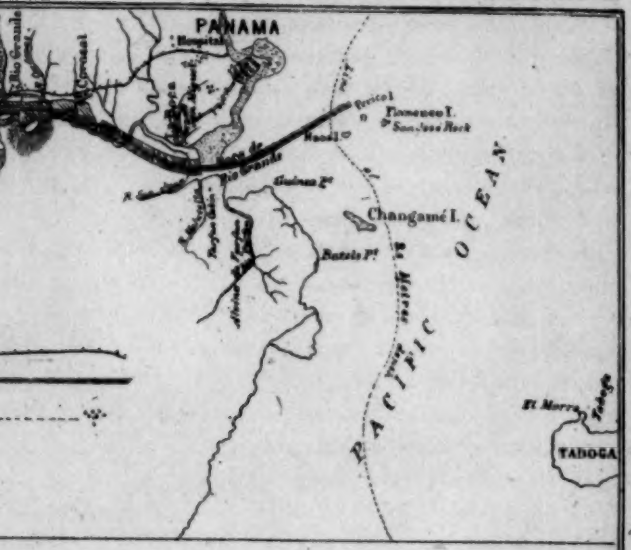


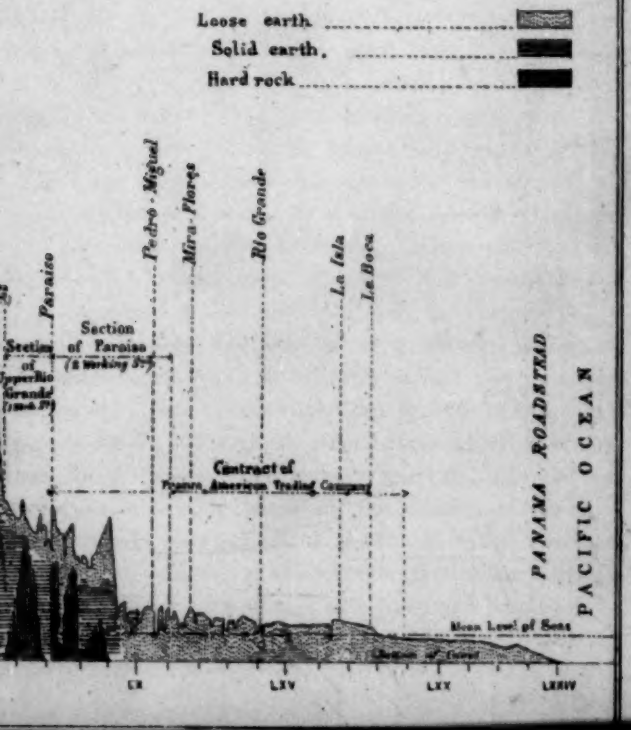
ROFILE ALONG THE AXIS OF THE CANAL

Heights amplified 100 times over lengths.

Scales {Heights / Lengths 1 in 237.100}




PANAMA
Changamé I.
PACIFIC OCEAN
TABOGA


Loose earth
Solid earth
Hard rock
Paraiso
Pedro-Miguel
Mira-Flores
Rio Grande
La Isla
La Boca
Section of Paraiso
Contract of
PANAMA ROADSTEAD
PACIFIC OCEAN
Mean Level of Seas
LX
LXV
LXX
LXXIV

of the Panama Railroad, and by this means has secured the help of this road for the transportation of machinery, materials, etc. This enables the works to be prosecuted at many points at once, since the railroad is almost parallel to the line of the canal at all points except between Gatun and Buhio Soldado, and on the Panama end where the canal runs on to La Boca, instead of ending in Panama, as the railroad does. In these places tracks have been laid to the main road.

At a later period it is proposed to excavate at each end of the canal, in the lowlands, two large basins where ships may lay by for repairs or for any other cause, thus producing safe and quiet harbors in smooth water. Each basin will be about 120 acres capacity. The total of excavations reported to September 1st, 1884, is 10,224,882 cubic yards. The Canal Company has put up a number of houses all over the line, for the use of their employés and workmen.

PROBABLE OPENING OF THE CANAL.

Mr. de Lesseps, the President of the Company, at the last annual meeting of the stockholders has again reiterated that, except in case of unforseen circumstances, the canal will be open for traffic in 1888. This is no idle promise. It is founded upon the assurance of the Chief Engineer in charge of the work at Panama, Mr. Dingler, a member of the Engineer Corps of France, endorsed by the opinion of the Technological Consulting Commission in Paris. The company does not depend upon manual labor, as would appear from the 20,000 men who are now employed on the line, in order to finish the canal by the time stated, but a large number of labor-saving machines have been ordered, such as dredges, excavators, locomotives, derricks, tug-boats, cars, dump-scows, steam dischargers, portable engines, etc.

The following averages of efficiency have been made up from experience and careful calculations, counting twenty-four working days to a month: The large American dredges of the American Dredging and Contracting Co., 78,000 cubic yards per month for each, or 3,250 yards per day. Medium size French dredges, 60 horse-power, 26,000 cubic yards each per month, or about 1,080 yards per day. Large French dredges, 180 horse-power, average 52,000 cubic yards each. The theoretical average of excavators of the different styles on the Isthmus is 1,300 to 1,500 cubic yards per day, but the calculations

made only reckon them at 650 cubic yards, or 15,600 cubic yards each per month.

A black laborer on the Isthmus is capable of loading an 8 cubic yard car per day, but the average for each for digging and loading is only reckoned $2\frac{3}{4}$ cubic yards per day, or 64 yards per month for each laborer.

The dredges of the Franco-American Trading Co. will average 520 cubic yards per day, or 12,480 cubic yards per month each. French marine dredges, with dumping scows, for deepening channels, will average 65,000 cubic yards per month each. Centrifugal sand and dirt pumps for removing loose materials and discharging through pipes, are estimated at 650 cubic yards per day for each, or 15,600 cubic yards per month.

It is also estimated that each large dirt car will average monthly 292 cubic yards; each small hand car (Decauville system), 130 yards; each transporter, or endless band discharger, 39,000 cubic yards.

Therefore, to obtain a monthly average of 2,600,000 cubic yards of dry excavation, the following are required: 4,500 large dirt cars, 4,000 Decauville hand cars, 20 endless band dischargers.

For dredging, 40 dredges are required, each averaging 650,000 cubic yards per year. With this machinery it is calculated that it will take two years to do the dredging, and three years for the dry excavation; showing that if the dredging should only commence on the 1st of January, 1886, and the dry excavation on the 1st of January, 1885, it would still be possible to open the canal on the 1st of January, 1888. For any unforseen circumitances that may arise, there may be offset all the dry excavations made up to January 1st, 1885, and the dredging up to January 1st, 1886, and one whole year to spare 1888, besides.

To carry out the work to completion by the time specified, 1888, there is required 10,460 cars, 250 locomotives, 44 dredges, 3 hopper barges, 10 hand dumping scows, 34 lighters, 97 portable engines, 100 excavators, 325 pumps, 50 earth elevators, 20 endless band transporters, 56 hoisting apparatuses, 38 steam windlasses, 814 hoisting engines, 260 miles of rails, 4 steamers, 30 towboats, 316 floating apparatuses of different kinds.

Out of this large amount of machinery there has already been sent, or is now on the way to the Isthmus: 72 portable engines, 316 floating apparatuses, 30 towboats, 4 steamboats, 21 dredges, 260 miles of rails, 8,960 cars, 122 locomotives, 814 hoisting engines, 38 steam

windlasses, 56 hoisting apparatuses, 256 pumps, 20 endless band transporters, and 79 excavators. The details of these estimates are too many to be discussed here, but from the fact that Mr. de Lesseps' assertion of the opening of the canal in 1888 is fully endorsed by the Technical Commission, made up of competent engineers attached to the company, it may reasonably be supposed that except in case of unforseen circumstances or accidents this promise will be redeemed. Moreover, it may be said that the opinion of several of our Navy officers, as shown by their reports, after inspecting the works, have expressed confidence in the successful completion of the work. Among them may be mentioned Rear-Admiral Cooper and Lieut. Rodgers, the latter having made two reports, one in 1883 and the other in 1884. Capt. Meade also made a favorable report in March, 1882. Lieut. Kimball, in the *Manchester Guardian*, of March 5, 1888, expresses the opinion that the canal will be finished in three or four years. Commander Selfridge, at the Paris Congress of 1879, expressed his strong confidence in the competence of its members and in their decisions, stating that the United States would accept all their deliberations. He showed his faith in their ability by voting for the Panama route in the fourth, or Technical Commission. When Mr. de Lesseps came to New York in March, 1880, a number of merchants and prominent gentlemen expressed their views freely in favor of the Panama Canal. So that it may be said there is every probability in favor of an early opening of the canal.

CLIMATE AND HEALTH.

On the Isthmus of Panama as in all intertropical countries there are two distinct seasons, the dry and the wet, the "verano" and the "invierno." The first commences about the end of November and the second during the month of May. There is a short cessation of rain, during the solstice of June of about twenty days.

The mean temperature at Colon for the year 1882 has been 79°, at Naos 80°, at Gamboa 58°; the two extremes are at Colon 64° and 94°, at Gamboa 52° and 98½°, at Naos 67° and 94½°.

More rain falls at Colon than any other point and less at Naos. Rains are the most abundant at Colon at the beginning of the rainy season in November, per contra at Naos, on the Pacific, the rains are the most abundant in May or June when the dry season is at hand. Gamboa about midway seems to be more subject to the influence of

the Pacific than of the Atlantic ocean, and the rains are also greatest during May.

The tides at Colon are but slight, varying from 1½ to 2 feet, while at Naos on the Panama side they rise and fall from 16 to 18 feet.

During the dry season the trade winds prevail, but in the rainy season the winds are feeble and variable. The air is always more or less charged with moisture; the climate is therefore debilitating, especially to the whites, but with ordinary precautions in diet and taking care not to be exposed to dampness and especially avoid to keep on wet clothing, ordinary good health can be maintained.

The records of deaths kept by the company show that during June, July and August, 1883, the proportion has been 3 per thousand; from September, 1883, to March, 1884, 5½ per thousand, and for April and May, 1884, again 3 per thousand. The company has provided a full corps of physicians to attend to the workmen and employes distributed all over the line. A fine and large hospital has been put up at Panama; Colon has also a hospital built on the sea-side, small post hospitals are distributed over the line. Nothing has been spared to provide for the health and comfort of the workmen, now numbering about 20,000, mostly blacks from Jamaica, some natives, and men of different nationalities.

The demands for labor has created a strong emigration from Jamaica to the Isthmus, and shiploads upon shiploads of blacks are discharging constantly. These men used to a warm climate resist the debilitating effect of the Isthmian climate better than laborers from northern climates.

Since a falsehood well repeated may be looked upon as truth, it may not be inappropriate to refute again here one of the popular stories told about the insalubrity of the Isthmian climate. It is popularly believed that there is a man buried on the Isthmus for every tie laid on the railroad. To prove the absurdity of this story it is an easy matter to make a calculation. The Panama Railroad is about 47½ miles long, it requires about 74,000 ties for that distance so that according to popular belief there are 74,000 men buried on the Isthmus in consequence of building the railroad. At no time has the railroad company had more than 4,000 men altogether on the railroad works. Modern arithmetic is insufficient to solve this problem.

ORGANIZATION OF THE COMPANY.

The Universal Interoceanic Canal Company has been organized

under the French law for the formation of corporations and copartnerships, dated July 24, 1867, now in existence. This law contains very severe provisions for punishment against maladministration or mismanagement of the Board of Directors and officers of the Company, varying from 500 to 10,000 francs fines, and imprisonment from fifteen days to six months.

Agreeably to this law of July, 1867, Mr. de Lesseps entered articles of incorporation and by-laws before notaries public in Paris, on the 20th of October, which are now in existence and regulate the affairs of the Company.

These articles of incorporation are also in accordance with the requirements of the Law of Concession, No. 28, of May 18, 1878, granting certain privileges for the opening of an interoceanic canal through the Isthmus of Panama, as sanctioned by the Government of the United States of Colombia. This concession was granted to Lieut. Lucien N. B. Wyse, as the representative of the "International Civil Society of the Interoceanic Canal," who sold their rights and privileges to Mr. Ferdinand de Lesseps.

At the time the first subscription was opened it was intended to locate the central office in the country subscribing the largest amount. Subscriptions were opened in several countries of Europe and in the United States. France having subscribed the largest share of the capital, the offices of the Company were opened in Paris, and are now located at No. 46 rue Caumartin, in that city. The President of the Company is Count Ferdinand de Lesseps; the General Secretary, E. Martin. A Board of Directors, of 24 members, has been elected, and Mr. P. Daubrée appointed as Secretary.

The Company is represented in this country by the American Committee, composed of four members, Messrs. R. W. Thompson, ex-Secretary of the Navy, Chairman; Jesse Seligman, of the banking house of J. & W. Seligman & Co.; E. P. Fabbri, of the banking house of Drexel, Morgan & Co; Jno. W. Ellis, of the banking house of Winslow Lanier & Co.; all of New York, and Charles Colné, Secretary of the Committee. Their offices are located in the Mills Building, 15 Broad street, New York.

FINANCIAL.

Since the Canal Company has been organized four subscriptions have been put upon the market, as follows:

No. 1.	In December, 1880,	fs. 150,000,000 =	$30,000,000
No. 2.	In September, 1882,	fs. 109,375,000 =	21,875,000
No. 3.	In October, 1883,	fs. 171,000,000 =	34,200,000
No. 4.	In September, 1884,	fs. 105,975,000 =	21,195,000
		Francs 536,350,000	$107,270,000

Loan No. 1, only half paid; the balance of $30,000,000 is subject to call on three months' notice.

Loan No. 2 is full paid.

Loan No. 3 is full paid.

Loan No. 4 is payable in instalments between Sept. 25, 1884, and July 5, 1885.

The financial resources of the Company on the 5th of September last are shown as follows:

Cash on hand.....	fs.	85,647,424.64
Instalments due on shares....	fs.	147,500,000.00
Loan of September, 1884.....	fs.	129,000,000.00
	Francs	361,967,424.64 = $72,393,485

The Canal Company, through their representatives in this country, have disbursed about $22,000,000 for purchase of shares of the Panama Railroad, and in payment of machinery, materials, etc., purchased from our merchants and manufacturers.

Machinery, supplies, etc., are constantly being shipped to Colon; thus this country is deriving daily benefits from this foreign capital invested here.

CONCLUSION.

It is not my purpose here to describe the special and marked advantages that commerce and navigation will derive from the opening of the Panama Canal. I believe it is a well settled belief, here and abroad, that such a channel of navigation has become an absolute necessity. From the fact that two competitors are in the field with the Panama Canal, the proposed Nicaragua Canal and the ship railway by way of Tehuantepec, it would seem that such enterprises must be thought profitable and necessary. It is a question for capitalists to decide whether one canal is sufficient, or whether we must have another by way of Nicaragua and a ship railway besides. The Panama Canal Company, I am sorry to say, has often been misrepresented in this country. Under the pretence that we must have "our own canal" as it is termed, another project has been brought before the people and

urged as an "American Canal." How a canal cut through foreign territory precisely as the Panama Canal is, can be more of an "American Canal" is not exactly clear to the mind. If the fact that American money invested in this enterprise will make it an American Canal, per contra, many of our railroads must be foreign roads, because many of them are built with foreign capital. Yet when this capital was proffered to us from abroad, common sense dictated to us that we should not refuse such a help; the man who would take a different view would be looked upon as of unsound mind. Our railroads are American because they are upon American territory. The Panama or the Nicaragua Canals cannot be American because they are not upon American territory.

The pretence that American money would give an American character to a Canal by the way of Nicaragua can scarcely be maintained in the face of friends of this enterprise making statements that money for its construction would be raised in England without any difficulty.

Upon the engineering difficulties of this route I shall not comment. The decision of the Paris Congress of 1879, I accept as sufficient as Admiral Selfridge did at the time of its meetings. This would seem to be qualified and sufficient authority.

On the other hand it is urged that in case of war the Canal should be controlled by America. All the diplomacy in the world and the fine spun sophistry of diplomatic correspondence does not amount to a feather's weight in case of war. All treaties and so-called solemn obligations are cast to the winds in the face of war. War is brutal and uses brutal means, it is a question for the best ships and best artillery to settle, and not one for pen and ink. It is not worthy of a great nation like ours to invoke such reasons against the prosecution of a maritime canal. It is against our self-interest to oppose it, and if I can find no higher and nobler motives to appeal to, let us at least not be blind to a question affecting our prosperity. I know of no parallel case of opposition to a universally recognized worthy enterprise except it be the inexplicable fear of the English against the boring of a comparatively small mole hole under the channel between France and England. I trust we shall not use that as one of the arguments to strengthen our opposition. How such a small hole can throw into convulsions of fear some of the so-called eminent men of England is beyond the comprehension of the average mind. Mr. de Lesseps, in his past experience in building the Suez Canal, has met with the same opposition from so-called leading men in England. The history of all

great enterprises has been one, in many instances, of continual opposition and positive assertions of failure, from great men who have often lived long enough to discover that their greatness did not lie in that particular line of prediction.

It is puerile for a great nation like ours to take the attitude of the dog in the manger, and invoke trivial and unsound reasons for opposing the completion of one of the enterprises that will outlive the history of our times by many and many years. I have had occasion in my official capacity to ascertain the views of Mr. de Lesseps, the President of the Panama Canal Company, and I say to you as I have said it two years ago in this hall, that whoever represents him as antagonistic to American interest and cherishing anti-American views, deliberately misrepresents him. Mr. de Lesseps is too much of a cosmopolitan to entertain the narrow views of the intensely national but misguided citizen, who can see nothing beyond the boundaries of his native land. If he were not actuated as he is, by broad and liberal views, there would still remain a question, which with us is seldom if ever overlooked, that of self-interest; for it is well known that the United States will be the best customer of the interoceanic Canal.

Moreover, have we not a sufficient guarantee that the Panama Canal is not being built as an antagonistic enterprise to American interest, when we find such men as the Hon. R. W. Thompson, the ex-Secretary of the Navy, connecting himself with the Company as a representative of American interests? The same may be said of the members of the American Committee, gentlemen well known for their national feelings. Is it reasonable to suppose that men of their reputation would attach their names to any enterprise having the least flavor of anti-Americanism?

However, I have a better opinion of my fellow-citizens than to suppose that this uncalled for spirit of opposition extends to any distance beyond the limits of a few interested patriots. I have confidence in American intelligence and American fair play, the outgrowth of our liberal and free institutions, and no man nor any set of men can hope to mislead the people for any length of time. We think and act for ourselves, and the public mind is the indication for leaders. If we ever travel in the wrong path we are not slow to discover it and change our course; if we unintentionally do wrong we are not ashamed to acknowledge it and repair the damage. Were it otherwise it would not be American.

GLIMPSES OF THE INTERNATIONAL ELECTRICAL EXHIBITION.

By Prof. E. J. Houston.

Comprising the substance of remarks made by request, at the Stated Meeting of the Institute held, Wednesday, October 15, 1884.

No. 1.—Telephoning Without Wires.

Professor Houston remarked:—After consultation with our President, I have concluded that it will not be advisable in the limited time of a single meeting to attempt to discuss all the topics mentioned since that would be more than can comfortably be completed. I will, therefore, confine myself this evening to a few remarks on the subject of telephony. I wish, however, to be distinctly understood that I do not mean to attempt to describe all the varieties of telephones exhibited at the Exhibition, since that would take longer than the time at our disposal. I wish rather to call your attention to a few of the many novelties in telephony which were presented by the various exhibits, and I believe that we can find abundant material if we consider some of the apparatus exhibited by Prof. Alexander Graham Bell, and by Prof. Amos E. Dolbear.

The mechanism of the magneto-electric telephone is so generally understood that I need not stop to describe it. This species of telephone, as you are well aware, is a contrivance by means of which speech is readily transformed into electricity, the electricity so produced is transmitted over a conductor, and transformed at the other end of the conductor into speech. The telephone, therefore, is practically a dynamo-electric machine in which the steam engine for driving the same is replaced by the voice. The electricity so produced traverses the conducting wire and entering a second dynamo, which acts as a motor, produces motions in a diaphragm which result in the reproduction of the original speech.

Without going into any further description of the telephone permit me to call your attention to some very beautiful experiments conducted by Prof. Bell, which resulted in the discovery by him that the conducting wire, usually employed for transmitting the electric current, could be replaced by a beam of light. This discovery resulted in the invention of an apparatus called by Bell the *photophone*, and now

generally known under the name of the radiaphone. Noticing a photophone on exhibit in the collection of the Bell Telephone Company, I prevailed on the gentleman in charge of the exhibit to bring the instrument to the Institute, so that I might have the pleasure of showing it to the members and explaining the method by which it is operated.

Before doing so, however, it may be well to briefly review what has been done with apparatus of this character, and in this direction I cannot do better than to call your attention to an elaborate series of experiments conducted by Prof. Bell in connection with Mr. Sumner Tainter, an account of which is published in a paper read before the American Association for the Advancement of Science, in Boston, August 7, 1880.

The experiments carried on by these gentlemen were originally made with a view of studying the causes of the curious sounds emitted when a vibratory beam of light was permitted to fall on certain substances. These experiments were first carried on with the then rare element selenium, but they were afterward extended to other materials which were found to produce the same phenomena. Among some of the substances which they found would emit sounds when vibratory beams of light were permitted to fall on them are gold, silver, platinum, iron, zinc, lead, copper, hard rubber, celluloid, gutta percha, ivory, paper, and wood.

In order to produce these effects, alternations of light and darkness, following each other with a certain rapidity, were permitted to fall on plates of the substances named, when musical sounds were emitted, the pitch of which was dependent on the rapidity with which the light and shadow succeeded one another. By properly modifying these alternations of light and shadow, even articulate speech was thus obtained.

It is not, however, to this method of causing light to produce sound that I wish to call your attention, but rather to the possibility of using a beam of light in the place of the conducting wire ordinarily used in telephonic communication. In order the better to do this it may be well to give some little attention to the properties of selenium, as this is the substance now used in connection with Mr. Bell's photophone.

Selenium was discovered in 1817, by Berzelius, while conducting a series of experiments on the refuse of some sulphuric acid works. Noticing a peculiar odor emitted by the refuse and ascribing it to the

then rare metal tellurium, he endeavored to separate this element from the refuse. Without asking your attention to the very excellent work he performed in this connection, I will simply mention that as the result of a series of elaborate experiments made on the refuse, he obtained, not the element tellurium for which he was seeking, but an entirely new element which he named selenium.

Selenium, as obtained by Berzelius, is a non-conductor of electricity. There are, however, different forms in which it can be obtained. If selenium is rapidly cooled from a fused state, a form known as the "vitreous variety" is obtained. This variety has a dark brown color, when in thin films, is transparent to ruby red light, and is a non-conductor of electricity. When, however, fused selenium is slowly cooled, a variety known as "crystalline," or "granular selenium" is obtained. This is opaque to light, is of a dull-lead color, and is a conductor of electricity.

The conducting power of selenium is, however, exceedingly slight, its electric resistance as compared to that of ordinary metals being enormous. It was the fact of its great electric resistance that induced Willoughby Smith to employ selenium in his system of cable testing and signaling during submersion, for the high resistance at the shore end of a submarine cable. When so employed, phenomena were observed, which eventually led to the invention by Mr. Bell of the photophone.

Although the introduction of the selenium resistance at the shore end of the cable readily afforded the high, artificial resistance required, yet Mr. Smith was exceedingly puzzled to find that its value was subject to remarkable fluctuations. Patiently investigating the cause of these variations of resistance, he at last discovered the exceedingly curious fact that the electric resistance of selenium is much less in the light than in the dark. He announced this discovery to the Society of Telegraph Engineers on the 17th of February, 1873. As might naturally be expected, this peculiar property of selenium was at once investigated by scientific men in different parts of the world, and several varieties of selenium, varying very greatly in their conducting power for electricity in the light and in the dark were obtained. For example, in February, 1876, Dr. C. W. Siemens, obtained a variety of selenium whose conductivity was fifteen times as great in the sunlight as in the dark.

Previous to the investigations of Bell and Tainter the variations

in the electric resistance of selenium by light were shown by the use of a galvanometer inserted in the battery circuit in which the selenium was placed. As long as the electric resistance remained constant the needle was motionless, but when light was flashed on the selenium, since a greater electric current then traversed the circuit, the needle of the galvanometer was at once deflected. Now, when Prof. Bell began his investigations on selenium, it occurred to him to replace the galvanometer by a telephone. From his knowledge of this latter instrument he readily appreciated the fact that in order to obtain its greatest sensitiveness, it would be necessary to cause a very quick succession of variations in the intensity of light to fall on the selenium; for, in the magneto-electric telephone it is only at the moment of change in the intensity of the current that any audible effect is produced by the diaphragm. He therefore rapidly varied the alternations of light and shadow by permitting an intermitting beam of light to fall on the selenium resistance. Under these circumstances a musical note was heard, the pitch of which was dependent on the rapidity with which the variations in the intensity of light followed one another. These experiments enabled him to announce on the 17th of May, 1878, in a lecture delivered at the Royal Institution of Great Britain, the possibility of hearing the fall of a shadow.

From these experiments the idea naturally suggested itself to him of employing a beam of light in place of the conducting wire ordinarily employed in telephony.

Now what must we have in order to apply the principles already explained as to the variations in the electric resistance of selenium by the action of light, to permit us to talk along a beam of light? We need a beam of light to replace the conducting wire. We need an arrangement by which this beam of light shall be varied in its intensity by the action of the voice, and a contrivance by which the beam so varied shall be permitted to fall on the surface of a selenium resistance which is included in the circuit of a voltaic battery and a telephone. Under these circumstances a person talking against an apparatus which we will subsequently explain, causes rapid variations in the intensity of the beam of light. These variations being imparted to the beam, produce corresponding variations in the amount of current that flows through the circuit. These in their turn produce in the diaphragm

of the telephone, movements, which are translated by the ear of the observer into articulate speech.

The most important part of a photophone is evidently the selenium resistance. These resistances are generally made in the form of what is known as selenium cells. Previous to the time of Bell and Tainter these cells were not in a condition suitable for use in connection with an ordinary telephone. The least resistance of any selenium cell being, I believe, about 250,000 ohms in the dark. Such cells, of course, could not be used in connection with a telephone. Messrs. Bell and Tainter, however, succeeded in making cells whose resistance is about 300 ohms in the dark, and about 150 in the light. It is such cells that are employed by them in connection with their system of radiaphony.

Messrs. Bell and Tainter attribute their success in lowering the resistance of their selenium cells to the use of substances like brass that exert a slight chemical action on the selenium. This action, in the opinion of Mr. Bell, prevents the selenium from acting towards other substances somewhat like greasy water does, and so ensures the contact of an extended surface instead of a series of minute contacts. The selenium cell we will employ this evening is formed of alternate metallic discs of brass separated by discs of mica, of slightly smaller diameter. The spaces between the brass discs over the mica, being filled with selenium. The alternate brass discs are connected together, as are also the selenium discs; that is to say, the selenium cell is coupled in multiple-arc.

Let us now inquire what must be done to the beam of light in order to permit it to be suitably varied in intensity by the action of the voice. As I understand Mr. Bell's invention in the art of articulate radiaphony, it consists in the use of an undulatory beam of light in distinction from a vibratory beam. He claims, I believe, that it is not possible to transmit articulate speech by means of a pulsatory beam of light, that is by means of alternations of light and absolute darkness. What he does is to produce variations in the intensity of the light that correspond with the variations in the amplitude of the sound waves produced by the movements of the plates of the diaphragm. This he accomplishes as follows: a parallel beam of light is permitted to fall on a flat plate of thin glass which is covered with a film of bright metallic silver. This plate is fixed at its edges in a manner similar to the diaphragm of the telephone. If, now, a speaker talks

against the back of the plate, the sound waves set it into vibration and cause it to become alternately convex and concave. These changes, you will readily understand, will result in alternately, causing the parallel rays of light in the beam to diverge and converge and thus to illumine the selenium cell more faintly or more brightly, but at no time to cut off all the light from it. In other words, the effect of the voice of the speaker against the plane silvered reflector is to produce undulatory, photometric variations in the beam of light that falls on the selenium resistance.

In order that you may be able to see these variations in the photometric intensity, I will illumine a cloud of smoke by means of a parallel beam of light. When now the voice is permitted to fall against the plate you will observe the very pronounced manner in which the breadth of the beam is altered.

Mr. Wilson, of the Bell Telephone Company, who had charge of the Bell exhibit at the Exhibition, has kindly consented to operate the apparatus for me, and I will now show you in actual operation, the process of talking along a beam of light. The limits of our lecture-room would naturally prevent a fair trial as to the success of the experiment, since any remark a speaker made at one end of the beam of light could be distinctly heard across the air space by the observer at the telephone. I have, therefore, connected the telephone by means of a metallic circuit with a room on the floor above, and an observer in that room will be able to hear all that is spoken against the plate in the lecture-room.

The light we will use for this purpose is the lime light. Arranging the lenses of the lantern so as to obtain a parallel beam of light, I allow it to fall on the plane silvered mirror before described. When, now, we talk against the plate, the beam of light is caused to vary in the manner we now see, and this undulatory beam falling on the selenium pile, which as we see is placed at the focus of a parabolic reflector, produces corresponding variations in the current that traverses the circuit of the battery and so permits articulate speech to be reproduced in the telephone.

Another experiment in telephony made at the exhibition may not be devoid of interest. I allude to the experiment tried by Professor Dolbear with his ingeniously constructed electro-static telephone. This instrument, as you are aware, is not magnetic in its action, and works on a principle entirely distinct from that of the magneto-electric

telephone, the vibrations of the diaphragm being caused by the attractions and repulsions produced in two parallel conducting plates. The peculiarity of this experiment consists in the fact that with this instrument we can telephone, not only without wires, but without even a beam of light. Holding a telephone to the ear and having its terminals not connected with any metallic conductor at all, we can walk around a room and yet in all positions hear what a person is saying, who is talking into the telephone at the other end of the line. When I speak of a room, however, you will understand that I refer to a room of the size of that occupied by Professor Dolbear at the Exhibition, which was about eight feet square.

If you regard this experiment as being somewhat incredible, I can assure you of its truth for I have tried this experiment myself. The phenomenon, however, is difficult to understand; indeed, like many other surprising things in science, it is difficult to explain why such an experiment was not tried sooner, but as we all know, it is those very things that are apparently so simple that require the greatest ingenuity to originate.

The explanation of the phenomenon, as I understand it, would appear to be somewhat as follows: One of the plates already referred to, being connected through the body of the observer to the ground, is thus joined to one end of the telephone circuit; the other plate is connected to the other end of the circuit by a line of polarized air particles. The experiment is simply an exceptional application of the principles of electro-static induction, and I am not at all sure but what it may be susceptible of a great increase in delicacy and thus become of considerable commercial value.

MR. OUTERBRIDGE remarked:—The very interesting explanation of the photophone is exceedingly clear in every respect, and I think every one in this building will understand just exactly the method by which the action of a beam of light carries sound, but at the beginning there was a statement made which Professor Houston may have made inadvertently, or it may have been a mere *lapsus linguæ*, and I should be glad to call it to his attention. Professor Houston said a beam of light falling upon a selenium cell, or on other metals would cause a sound. Is it actually so?

PROFESSOR HOUSTON:—The statement I have made concerning the

audible sounds which selenium and other substances emit when a vibratory beam of light is allowed to fall on them, are vouched for by Professor Bell, and will be found in a paper which he read before the American Association for the Advancement of Science, in Boston, in August, 1880. He found that when plates of these substances were simply held to the ear and light was permitted to fall on them that sounds were distinctly heard. I believe he found that these phenomena were more marked in the case of thin plates of the materials and ascribed the cause of this circumstance to the fact that the action of the light was a surface action.

DR. WAHL:—I would like to ask Professor Houston if any success has been made in interpreting the sounds transmitted by the photophone?

PROFESSOR HOUSTON:—It is not all that one might desire, though I could understand, I suppose, all that was spoken; but you will understand that the photophone is an exceedingly delicate apparatus, and in the hurried and necessarily clumsy way in which we have it arranged, we cannot expect to be able to hear everything distinctly, but I could distinctly understand words and distinguish musical sounds.

ELECTRIC LIGHT IN THEATRES.—M. Brandt places alternately in a continuous line, forty lamps of ordinary glass, forty of green glass, and forty of red glass, making a hundred and twenty lamps in all, at the foot of the stage. Each series of forty lamps forms a separate circuit. The three series can be lighted independently, or they may be combined, in order to obtain different effects of color. For example, a delicate rose hue may be produced by simultaneously lighting the red and the white lamps; a moonlight effect, by a combination of the white and the green lamps. In order to pass gradually from the latter to full daylight, it is only necessary to increase the resistance in the green circuit while strengthening the current in the white lamps. Moreover, the two sides of the stage may be lighted independently, because the 120 lamps are again sub-divided into two circuits of sixty each. We may thus have a moonlight on one side of the stage, while the other side, at the moment when an actor enters with a torch in his hand, seems to be illuminated by the reflection from the torch. When the footlights are of gas, a current of hot air ascends above the whole line of lights, forming a sort of gaseous wall between the stage and the audience, which often makes it difficult to hear the actors. This inconvenience is suppressed by electric lighting, and the opera singers are agreeably surprised at the great improvement.—*Lumière Electr.*, May 24, 1884. C.

CORRESPONDENCE.

AN ITEM OF HISTORY, AS TO THE IDEA OF MAKING THE PARTS OF GUNS INTERCHANGEABLE.

Committee on Publication, Journal of the Franklin Institute:

It has become in some sort customary for writers in American newspapers and magazines to claim as a distinctively American contrivance the constructing of machines and implements, and particularly firearms, with interchangeable parts; that is to say, the making of each of the parts of any one machine so precisely like the corresponding part of every other that it will fit one machine as well as another, and in case of such substitution can serve its proper purpose as well as the part which it has replaced. Recently, Mr. Charles H. Fitch, in an apparently carefully prepared paper entitled "The Rise of a Mechanical Ideal," which was published in the *Magazine of American History*, for June, 1884 (page 516), while admitting that "the plan of uniformity in firearms was attempted in France in 1783, and was noticed by Thomas Jefferson . . . . who advised the purchase by the United States Government of French arms having the feature of uniformity, but nothing came of it;" and urging, with evident justice, that "we find in the history of this manufacture a series of men who were imbued with the idea and pushed it to successive degrees of mechanical perfection;" has said explicitly, "first of these was Whitney, inventor of the cotton gin, who introduced some of its most essential administrative features at his armory at Whitneyville, Connecticut, which was established before the close of the last century. Next, Hall invented a breech-loader, designed with especial reference to its interchangeable manufacture. . . . etc."

I would submit, that as a mere matter of historic fact, and solely as concerns the question of priority, it may possibly be open to doubt, whether the foregoing statement can be made to harmonize with the following remark of Professor Erman who, traveling into Siberia in 1828, wrote as follows:* "Leo Sobakin (born in 1742) was a serf in the Government of Tver. He early displayed great mechanical ingenuity and was sent to England to study. On his return to Russia he was appointed superintendent of the machinery at Ije. Of the apparatus erected or brought into use under his direction, much was undoubtedly invented by himself, and was quite original. It conduced much, for example, to the perfection of the firearms made at Ije that every piece was made there according to a model, and if it did not exactly fit or correspond with that model was rejected by the overseer. The system of shaping the several parts by simple pressure was also carried to a great extent. All the pieces of the same denomination in Russian arms are consequently so perfectly equal or alike that the experiment has often been successfully made of taking to pieces a large number of muskets and then from the promiscuous heaps of similar parts to put them all together again."

F. H. Storer.

Bussey Institution, September, 1884.

* See the 172d page of the first volume of his "Travels in Siberia," *i. e.*, the English translation of his "Reise um die Welt durch Nord-Asien."

Committee on Publication, Journal of the Franklin Institute:

GENTLEMEN:—In a recent issue of your JOURNAL a writer over the initials "H. B." gives a notice of my "Treatise on Toothed Gearing," which seems to me to be unfair and erroneous; I trust you will therefore allow me brief column space in which to defend my little work. Figure 12 in my book (the figure to which "H. B." takes most violent exception) was drawn without regard to accurate shape of the tooth profiles, and the first point of contact between the teeth shown was unfortunately drawn so close to the pitch point that the engraver carelessly made the points coincide. In my original drawing, which is before me, these points do not coincide, and there are arcs drawn through both points instead of the one shown in the book. The small rolling circles—which should be dotted—are assumed circles and are drawn small because the generating circles for cycloidal profiles are, in practice, always smaller than the pitch circles. The two points of contact between two working teeth mentioned by "H. B." are on separate teeth and are so explained in the book. I passed over the subject of "interchangeable gears" briefly in order to save space and because I believed the small space given to it sufficient for a general understanding of the subject. I make use of the circles at the bottoms of involute teeth as the evolute circles because I believe it best; it gives stronger forms and, according to my experience, as accurate profiles. The statement that radial flanks are used in involute teeth is *not* incorrect.

The teeth of my Figure 66 were drawn off-hand with a common pen, and are not supposed to be accurate, since the figure simply illustrates a principle. I notice that Reuleaux, in his "Constructeur," gives a precisely similar sketch, and states that the contrivance is in actual use in an astronomical clock at Prague.

Notwithstanding the fact that my Figure 100 was drawn hastily with the compasses, and not "designed," if "H. B." will measure the peripheries of the gears there represented by any more accurate method than that of "placing the square wheel inside of its mate," he will find that they are very nearly equal, although this fact has no important connection with the method illustrated by the figure. I believe that practical machinists and artisans, for whom the book was written, will be in no danger of becoming "hopelessly confused," but will find my Treatise as simple, and clearly explained as the complicated nature of the subject will allow.

J. HOWARD CROMWELL.

Committee on Publication, Journal of the Franklin Institute:

GENTLEMEN:—Allow me to answer Mr. Bilgram's communication to you, published in the October number of the JOURNAL, page 307, in regard to "Tests by Hydrostatic Pressure."

The quoted statement was not made by me at the meeting of the Institute, but added the same when I read the proof, where I first noticed Mr. Bilgram's remarks upon the force of impact in connection with velocity of sound, etc.

The question of force of impact which I elucidated at the meeting of the Institute, is based upon well-known and established physical laws, which are

abundantly confirmed in practice, and for which laws I am not responsible. Mr. Bilgram sets himself above, and defies the laws of nature in saying that "The alleged pressure resulting from impact is simply another instance of the anomalies at which theorists arrive." The "theorist" in this case is the Creator of the universe, who has established these laws, and to whom I refer Mr. Bilgram for redress of his grievances. It is not my fault that these laws do not agree with Mr. Bilgram's notions of what they ought to be. Mr. Bilgram says that "the principal factor in the phenomenon is friction of water in the pipe." Mr. Bilgram is in error about the friction being the principal factor in the phenomenon. Under the very high pressure in a hydrostatic test, the friction is of no importance.

JOHN W. NYSTROM.

PHILADELPHIA, October 18, 1884.

OBITUARY.

ROBERT EMPIE ROGERS.

Robert Empie Rogers, the subject of this sketch, was the son of the late Dr. Patrick K. Rogers, of Philadelphia, and was born, in the year 1814, in the city of Baltimore. He was one of a notable brotherhood, all now deceased, who were distinguished for their scientific attainments. His eldest brother, James B. Rogers, successively occupied the chair of Professor of Chemistry in the Washington Medical College at Baltimore, the Medical College of Cincinnati and the University of Pennsylvania. Henry D. Rogers, another brother, was a noted geologist, best known, perhaps, by his great work on the Geology of Pennsylvania. William B. Rogers, still another brother, whose death occurred two years ago, was the President of the Massachusetts Institute of Technology.

Robert E. Rogers was educated at the University of Pennsylvania, and, after his graduation, turned his attention especially to the study of chemistry and toxicology, as the assistant of Prof. Robert Hare. The earliest scientific work in which he was engaged was in connection with the Geological Survey of Pennsylvania (conducted by his brother, Henry D. Rogers), on the official staff of which he served as chemist in the campaigns of 1837 and 1838. In 1844 he was elected to the chair of Chemistry in the University of Virginia, from which he withdrew in 1852 to occupy the same chair in the Medical Department of the University of Pennsylvania, made vacant by the death of his brother James. Dr. Rogers held this post for twenty-five years, during a considerable portion of which he was the dean of the faculty.

In May, 1877 he resigned his position in the University of Pennsylvania to accept the chair of Medical Chemistry and Toxicology in the Jefferson Medical College, a position which he continued to occupy to within a few weeks of his death.

Dr. Rogers' connection with the Franklin Institute began in 1852, in

which year he was elected a member, and this association, which was most active, useful and honorable, continued uninterruptedly until terminated by his death. In 1855 he became a life member. In 1857 he was elected to the Board of Managers, in which he served until the following year, when he was chosen Vice-President. This office he occupied continuously for a period of eighteen years, and in the year 1875 was elected to the highest office in the gift of the Institute, that of President. This post of honor he filled for four years, from 1875 to 1878 inclusive. In 1879, declining a re-election, he was again elected to the Board of Managers, of which he was a member at the time of his death.

During most of the thirty-three years of his connection with the Institute, Dr. Rogers was prominently identified with its work. He was for many years an active member of the Committee on Instruction, and delivered several courses of lectures before the Institute on chemistry, electricity and kindred subjects.

He served also upon numerous special committees, the most notable of which were that engaged in the tests of the efficiency of dynamo-electric machines and the committee to investigate the dangers of electric lighting. Of both these committees he was the chairman, and the results of their work, which are recorded in the JOURNAL, were highly creditable. The investigation of the comparative efficiency of the dynamo-electric machine, indeed, was the first that had been made, and the work of the committee has a permanent value.

As a teacher and lecturer, Dr. Rogers had eminent qualifications. He had thorough command of his knowledge, and could easily and quickly avail himself of it. He was a fluent and eloquent speaker, and by the dignity and impressiveness of his manner, the elegance of his diction, his clearness of statement and his admirable skill as an experimentalist, he enjoyed a rare degree of popularity. The announcement that he was to lecture was sufficient to crowd the lecture-room of the Institute to the limit of its capacity, and many, doubtless, who read this tribute to his memory, will recall with pleasure the interest and enthusiasm which his presentation of a subject was sure to excite.

Dr. Rogers was a mechanic of no mean attainments, and made a number of inventions, the most notable of which, perhaps, is the form of steam generator known as the "Rogers & Black Boiler."

He was the author of a number of medical treatises, and contributed many papers on medical subjects to the scientific journals. His most recent literary work was the editing of an American reprint of Lehman's Physiological Chemistry.

In his intercourse with others, Dr. Rogers was distinguished by an unvarying affability and courtesy of manner; and they who enjoyed his friendship and intimacy, will cherish his memory as that of a most amiable, genial and accomplished gentleman.

At the time of his death, which occurred on the 6th of September, 1884, Dr. Rogers was in his 71st year.

J. E. MITCHELL,
EDWIN J. HOUSTON,
ISAAC NORRIS, M. D.,
CHAS. A. CRLSSON, M. D.
GEO. M. WARD, M. D.,
WILLIAM H. WAHL., PH. G.

Franklin Institute.

[*Proceedings of the Stated Meeting, held Wednesday, October* 15, 1884.]

HALL OF THE INSTITUTE, October 15, 1884.

The President, Mr. William P. Tatham, in the Chair.

Present, 197 members, and 31 visitors.

The President, upon calling the meeting to order, remarked: "I desire to say, on behalf of the Managers of the Electrical Exhibition, which was closed last Saturday without ceremony, that we express our gratitude to the Almighty, that the prosperity which was invoked at the opening of the exhibition was continued to the close. The chairman of the general committee is present, and, no doubt, will be glad to make a verbal and necessarily imperfect report of the results of that exhibition. It will be his duty hereafter to make a detailed report to the Board of Managers. This will be published, and he will then have the pleasure of giving the credit which is due to everyone who has been concerned in the exhibition and contributed to its success. In case he, with his characteristic modesty, should omit to mention himself, I desire to mention his part myself.

"Col. Banes has been the chairman of the standing 'Committee on Exhibitions' for a number of years, during which he had only to watch his opportunity. This opportunity at last arrived and the Board of Managers then charged him with the care of the exhibition, and clothed him with adequate and corresponding power; and I must say that he has exerted those powers with excellent judgment, moderation and success. His clearness of perception and his energy in direction, his quickness of decision and execution, and his admirable judgment, have made him the very model of a manager for the electrical exhibition."

Col. Banes remarked:—"Mr. Chairman, I desire to thank you for the very kind and flattering words that you have said. Permit me to say through you, to the members of the Institute, that any report that I can make at this time would, of course, be exceedingly imperfect. In the first place we have not by any means closed our financial affairs, and certain very important matters yet in progress will probably require two or three weeks before they are settled.

"The exhibition has been successful, as you all know, from more points of view than one. Some few months ago when I had the honor to make the motion that we should have this exhibition, a gentleman whom I respect very highly said to me 'Are you going to take a leap in the dark?' but I felt that the Franklin Institute had the reputation to make it a success, and that we were close to success in this enterprise. From the very first I do not think there has been any doubt of it. We did not expect at all that we would make any profit, but there has been such a generous spirit shown by the members of the Institute and by the public generally, that we are able to report that, after paying for the building, shafting, steam power, etc., there will probably remain a balance of about $10,000.

"I desire to say a few words in connection with the progress of the enterprise: In the first place, it was early determined that this exhibition should be very largely educational, and, for this reason, the Committee determined on publishing a little paper called the 'Bulletin of the International Electrical Exhibition,' which some of you have seen. This paper has been published every two weeks, and I speak of it for the reason that quite a number of gentlemen connected with the Institute have written for it, and as it was determined to distribute it as largely as possible, we have kept no duplicates on hand.

After the paper was started, it was determined to bring the exhibition to the attention of the schools, and the gentlemen of the Board of Public Education decided to permit the pupils of the Central High School, the Normal School, and the Grammar Schools to attend the exhibition. To make these visits profitable to them we succeeded in arranging for guides to describe to them the instruments and electrical machines, and, by way of greater encouragement, offered prizes for compositions. This has excited great competition and the prizes will soon be awarded to the successful ones.

"In addition to the public schools of this city, there were sixty-five from outside of Philadelphia that visited the exhibition, some coming from long distances and some remaining more than a day.

"In addition to this, a series of 'Electrical Primers' was prepared, giving in simple language explanations of the principal electrical appliances. These primers were offered for sale at a nominal price, and had an enormous sale. Arrangements were also made with a number of eminent gentlemen to deliver lectures on subjects relating, more or less directly, to electricity. These lectures were held in the lecture room of the exhibition on two evenings of the week during the continuance of the exhibition, and attracted large audiences.

"The total number of visitors was about 290,000. Of these visitors, 22½ per cent. were what is called complimentary, that is, members of the Institute and those to whom complimentary tickets were given for various reasons. The largest attendance was, I think, on October 7th, when we had 17,047. The smallest attendance was on September 3d, when we had 2,830. The average attendance during the entire exhibition was 8,507.

"I desire also to call your attention to the fact, that we were greatly aided in adding to the success of the exhibition by numbers of scientific gentlemen and professors from different parts of the country, who not only loaned their instruments for exhibition, but also loaned them for the use of the 'Committee on Tests and Measurements,' which Committee is still at work, is doing good work, and will be occupied for three or four weeks longer. We are also exceedingly obliged to the Government of Canada and to our own Government for the aid they have afforded.

"I desire to say in concluding, that I hope that a motion will be offered this evening authorizing and directing our worthy secretary to extend to these departments and to the various gentlemen who have so kindly aided in the Exhibition, the thanks of the Institute."

At the close of Colonel Banes' remarks, Mr. Hector Orr, seconded by

Mr. C. Chabot, moved a vote of thanks to all who were engaged in conducting the Electrical Exhibition. The motion was carried unanimously.

The Special Committee appointed to prepare a memorial of the late DR. ROBERT E. ROGERS presented a report, which was adopted, and referred to the Committee on Publication. [This report appears elsewhere in the JOURNAL.]

Professor E. J. Houston, by invitation, made some remarks on the telephones shown at the late Exhibition. [An abstract of Professor Houston's remarks appears elsewhere in the JOURNAL.]

The following amendment to the By-Laws of the Institute was offered by Mr. J. D. Rice and seconded by Mr. J. B. Burleigh, viz. :

Amend Article III Section 1, by adding thereto as follows :

"Any member having paid annual dues to the amount of one hundred dollars is entitled to life membership with all the privileges attached thereto."

After considerable debate, the whole matter was postponed until the stated meeting in November.

The Secretary's report embraced remarks on the Cable Railway about being introduced in Philadelphia, the navigable balloon of M. M. Renard Krebs, and on several pernicious forms of so-called lightning conductors, said to be largely introduced in certain of the Western States.

Adjourned.

WILLIAM H. WAHL, *Secretary.*

ELECTRICITY IN COINING.—In spite of the greatest possible care, many of the pieces which are prepared for coins are either too light or too heavy. The first are remelted and the others are filed away until they have the proper weight. These operations cause the loss of valuable material, and interfere with the sharpness of the impression. W. F. Chandler Roberts, chemist of the London mint, employed an electric current in connection with suitable acid baths, in order to regulate the solution of superfluous metal, having ascertained that the quantity dissolved was exactly proportioned to the time, if the current was kept constant. He also provided, in a similar way, for the galvanic deposit of additional metal upon coins which were too light. In both methods provision was made for automatically breaking the circuit, when the right weight was reached. These processes cannot be applied at the London mint, where the law directs that every defective piece, whether too heavy or too light, shall be remelted ; they have, however, been used with great advantage at the mints of Bombay and Calcutta.—*Les Mondes*, May 31, 1884. C.

VARIATIONS OF BISMUTH IN A MAGNETIC FIELD.—In a note presented to the French Academy, at its sitting of May 19, 1884, M. Hurion cited recent experiments and researches of Leduc, Kerr and Righi, together with his own experiments which are still in progress, to show that the electric resistance of bismuth increases when it is placed in a magnetic field.—*Lumiere Electr.*, May 31, 1884. C.

INFLUENCE OF TEMPERATURE ON SPECTRAL RAYS.—Fievey has shown that the broadening of the spectral lines in hydrogen, nitrogen, etc., is independent of pressure, and corresponds with elevation of temperature. By recent experiments he has proved, in opposition to the declaration of Van Monckhoven, that pressure has no *direct* influence upon the breadth of the hydrogen lines, but the broadening is due to the resistance which is opposed to the current by the medium which it traverses. Hence he concludes that an increase of complexity in the constitution of a spectral ray is a sure index of an increase of temperature in the producing vapor. This conclusion justifies the inference that the temperature of the solar spots is greater than that of the limb.—*Bull. de l'Acad. Belg.*, No. 4, 1884. C.

OPTICAL MEASUREMENT OF ELECTRICAL CURRENTS.—Since 1878 Henri Becquerel has measured the absolute intensity of a magnetic or electromagnetic field by observing the rotation of the plane of polarization in the light traversing a body placed in the field. The indications of the apparatus are instantaneous; the optical measurement is easily made with great precision; an apparatus for absolute measurement can be easily constructed, and the method can be applied to very weak as well as very strong currents. A description of the method and of the theory on which it is based is given in *La Lumière Electrique*, May 31, 1884. C.

ATOMIC MOTION.—The law of atomic movement is expressed by the formula, $\frac{M v^2}{2} = \frac{4}{3}\pi\rho^3 Pg$, in which M represents the sum of the atomic masses in the molecule; v, the velocity upon the surface of a molecular sphere with a radius ρ; P, the external pressure; g, the constant of gravitating acceleration. Langlois deduces the same formula from the hypothesis that the molecular sphere is formed of thin layers of ætherial molecules which are identical with the ponderable molecules and serve for the transmission of external forces.—*Poggendorff, Beiblätter*, No. 5, 1884. C.

VARIABILITY OF SPECTRA.—In 1882 Stas showed Lt.-Gen. Liagre that, on examining the internal cone of a gas flame which was properly supplied with pure oxygen, spectra would be shown, by the same spectroscope, which were sensibly different in the number of lines, according as the observation was made at the summit of the internal cone, where the temperature is greatest and is sufficient to maintain iridium in fusion, or on the front, or on the side of the internal cone. He also showed that, if a direct spectroscope of small dispersion was used, the spectrum resembled the cometary band-spectrum; but in employing an instrument of greater dispersive power, the bands become lines, of various widths and very sharply defined.—*Bull. de l'Acad. Belg.*, No. 4, 1884. C.

ACOUSTIC EXPERIMENT.—M. Fouchs describes a curious little acoustic experiment. Having closed his ears so as completely to exclude all sounds, and then having conducted, by means of an acoustic tube, the voice of a speaker into his own mouth, he found that the *timbre* was entirely changed so that it ceased to be recognizable.—*La Nature*, May 31, 1884. C.

PREDICTIONS FROM SCINTILLATION.—Montigny has remarked the special predominance of the blue tint in the twinkling of stars, on the approach and during the continuance of rain. On June 2d, 1883, he predicted that the amount of rain during the year would be less than in the immediately preceding years, because the blue was less marked, and the green, which had characterized the fine weather of 1870 to 1876 was more frequent. The prediction was fully verified. For similar reasons he predicts a less frequency and less abundance of rain in 1884 than during the six years anterior to 1883, and he thinks that we are entering upon a series of finer weather.—*Bull. de l'Acad. Belg.*, No. 4, 1884. C.

A NATURAL BAROMETER.—The natives of the Chiloe Islands have a singular barometer, in the shell of a crab which is very sensitive to atmospheric changes It is almost white when the weather is dry ; it becomes spotted with small red points in damp weather and it becomes completely red when rain is falling. The accuracy of the indications has been confirmed by members of the Belgium Mission, who were sent to Chili to observe the transit of Venus and who brought back specimens of the shell.—*Ciel et Terre ; Les Mondes*, April 19, 1884. C.

HYGIENIC COMPARISON OF GAS AND ELECTRIC LIGHT.—Experiments have been made at the Theatre Royal of Munich, in order to determine the elevation of temperature and the amount of carbonic acid, under illumination by gas and by the electric light. Before the play, at the time of the experiments, when there were no more than ten or fifteen persons in the building, the curtain was raised and all the lamps were allowed to burn for an hour. The temperature was observed, at intervals of five minutes, simultaneously in the parquet, in the balcony and in the third gallery. During the plays, when there were on an average between 500 and 600 persons in the theatre, the thermometer was observed every ten minutes. The experiments showed that the electric light greatly diminishes the increase of temperature. It does not render ventilation superfluous, but it requires a less active ventilation than gas since it does not, like gas, contribute to the carbonic acid and to the increase of heat.—*Centralblatt für Elektrotechnik ; L'Electricien*, May 1, 1884. C.

LUMINOUS POWER OF INCANDESCENT LAMPS.—Preece's experiments show that the luminous power of an incandescent lamp increases as the sixth power of the intensity of the current. Since the energy expended increases only as the square of the intensity (or even less if we take account of the diminution in the resistance of the filament when the temperature increases) it follows that the luminous power varies as the cube of the energy expended and unfortunately the duration or life of the lamps diminishes rapidly with the increase of light. It would, therefore, be interesting to know the relation which exists between the life of a well constructed lamp and the intensity of current.—*L'Electricien*, May 1, 1884. C.

VARIABLE BRILLIANCY OF NEPTUNE.—Maxwell Hall has made numerous observations at Jamaica, which shows that Neptune is of a bluish tint, and that its brilliancy undergoes periodical vibrations, in cycles of 7 h.

55 m. 12 s., which are probably due to rotation. He calls attention to the remarkable succession of planetary hues, corresponding to the spectral colors. Mars red, Jupiter orange, Saturn yellowish green, Uranus light green, and Neptune bluish. Prof. Pickering has made numerous photometric measurements, at the observatory of Harvard University, which show a variation of brilliancy between 7·6 and 7·9.—*L'Astronomie*, May and June, 1884. C.

ELECTRICITY IN AGRICULTURE.—M. Lestelle has devised a combination for giving warning of approaching frosts. A thermometer, placed in a battery circuit, is so arranged as to close the circuit, when the external temperature approaches the point of danger. A commutator, moved by clockwork, transmits the current of a small Ruhmkorff coil into a series of circuits. An ingenious lighter carries a match, which is kindled by the induced current, and a fuse of gun-cotton, which lights several fires almost at the same instant. These fires are provided with materials which produce clouds of smoke and ward off the frost.—*Chron. Industr.*, June 1, 1884.

TEST OF GLUE.—The *Tischler Zeitung* gives the following method of testing glue. Carefully weigh a piece and suspend it in water, at a temperature not exceeding 10°C. (50°F.), during 24 hours. The coloring matter is then precipitated and the glue swells in consequence of the absorption of water. On removing the glue from the water the increase in weight will be found to be in proportion to the quality. The weight of the coloring matter can also be ascertained by weighing the glue a second time after it has been thoroughly dried.—*Chron. Industr.*, April 6, 1884. C.

PRIVATE ELECTRIC LIGHTING.—Electricity has been used in various ways for the illumination of private residences, but they are all costly. One of the best plans is that of Gaston Menier, who uses 150 Swan lamps of 40 volts and 0·7 ampère supplied by a series of 22 accumulators mounted in tension. The accumulators nominally yield from 40 to 45 ampères, which are sufficient to supply 60 lamps at a time, a number more than sufficient for ordinary occasions. The accumulators are charged each day by the aid of a continuous-current Gramme machine, excited in derivation, which is regulated by resistances introduced into the circuit. The machine is driven by a five horse-power Otto gas motor. With a little practice the servant who has charge of the lighting can accurately estimate the consumption of the evening and recharge the accumulators, allowing an excess of ten or twelve per cent. for losses and possible errors. When it is necessary to use nearly all the lamps, the direct supply from the machine is added to that of the accumulators.—*La Nature*, May 31, 1884. C.

FAYE'S COSMOGONY.—Faye supposes that the primitive nebula had no central condensation, but that it was nearly homogeneous and spherical, not rotating, but having feeble interior gyrations in a given direction. Under the influence of internal gravity these slow gyrations formed rings, situated nearly in the same plane. These rings successively gave rise to planets, beginning with the smallest, which were nearest the centre. The rotations of the planets and the circulations of their satellites were then all

direct. During this time a central condensation was going on, becoming gradually more rapid. When the sun had absorbed all the nebula except the planets and the exterior rings, gravity, instead of varying directly as r, varied inversely as r^2. Uranus and Neptune, which were both in the form of rings, were forced to take a circulation in conformity with the new law. Neptune was entirely under this law; its rotation and that of its satellite were, therefore, markedly retrograde. Uranus was still partly influenced by the primitive nebular rotation so that its rotation is neither direct nor retrograde, but its equator is nearly perpendicular to the plain of its orbit. This hypothesis supposes the earth to have been formed before the sun so as to give geology and the natural sciences the use of all the solar heat in terrestrial organization. It also recognizes comets as parts of the solar system.—*L'Astronomie*, June, 1884. C.

[The internal gyrations are such as would result from Herschel's "subsidence" theory. The fact that earth is at the centre of the belt of greatest density was pointed out by Chase, (*Proc. Amer. Phil. Soc.*, Vols. x., seq.)]

Sand, Bricks and Stones.—M. Hignette, in the *Bulletin technologique des Ecoles nationales d'Arts et Métiers*, describes a new ceramic product from the waste sands of glass factories, which often accumulate in immense quantities so as to occasion great embarrassment. The sand is subjected to an immense hydraulic pressure, and then baked in furnaces at a high temperature, so as to produce blocks of various forms and dimensions, of a uniform white color, which are composed of almost pure silex. The crushing load is from 370 to 450 kilometres per square centimetre. The bricks, when plunged in chlorhydric and sulphuric acids, show no trace of alteration. The product has remarkable solidity and tenacity; it is not affected by the heaviest frosts or by the action of sun or rain; it resists very high temperatures, provided no flux is present; it is very light, its specific gravity being only 1·5; it is of a fine white color, which will make it sought for many architectural effects in combination with bricks or stones of other colors.—*Chron. Industr.*, May 25, 1884. C.

Intensity of Current in Geissler Tubes.—The galvanometer of Deprez d'Arsonval has been applied to the measurement of the current which is necessary for the illumination of a Geissler tube. The galvanometer was regulated to give a scale division for each hundredth-millionth of an ampère. At the moment of illumination the current was 3,500 micro-ampères; it was gradually reduced until there was a sudden extinction at 150 micro-ampères. The experiment points to great advantages which may result from the use of the galvanometer in measurements of small intensities.—*L'Electricien*, June 1, 1884. C.

Electricity and Vapor.—According to the experiments of L. J. ("Annalen der Physik," 1883, p. 518) there is no evidence of the development of electricity during the conversion of water into steam; even upon quiet electrified surfaces the steam which arises is electrically neutral. S. Ralisher has also shown that no electricity is developed by the condensation of atmospheric vapor.—*Dingler's Journal*, May 28, 1884. C.

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(Concluded from page 320.)

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North Atlantic. Pilot Chart of. For January, 1884, with Supplemental Pamphlet. Washington. From the Hydrographic Office, Navy Department.

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Amended Specification No. 2173 of 1877. London.
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Specifications. Vols. 16, 18, 19, 28, 29, 31–34. 1883. London.
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From the Commissioners.

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[This is a work translated, compiled and published under authority of the Commissioner of Patents. Inventors and others interested in this subject will doubtless be glad to hear that at last a key has been supplied to this important publication and that by the Government of the United States. E. H.]

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Faculty and Instructor. From the College.

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